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An Analysis of Air Pollution and Its Health Effects: Washington, DC. Metropolitan Area

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This study represents an extension of research begun under a contract (No. 68-01-3144) funded jointly by the U.S. Environmental Protection Agency and the U. S. Department of Transportation entitled, "Air Pollution and Health in Washington, D. C.: An Analysis of Some Acute Health Effects of Air Pollution in the Washington Metropolitan Area." In the original study three basic categories of data were analyzed: health information, air quality measurements, and weather factors. Since undertaking that analysis, additional air pollution and weather data became available. This study has attempted to examine the implications on our previous conclusions of analyzing this expanded data base.

The study period was again 1973-74 and focused on the Washington, D. C. Metropolitan Area. Statistical models were formulated to test the hypothesis that air pollution can aggravate the health status of a population and can result in increased utilization of certain types of medical care services. The statistical results indicated that air pollution levels had a very limited effect on the health-care utilization of the group practice even after the additional air pollution and meteorological data were examined.

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AN ANALYSIS OF AIR POLLUTION AND ITS HEALTH EFFECTS:
Washington, D.C. Metropolitan Area

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FROM: John A. Jaksch
Project Officer

TO: Karen Randolph
Technical Information Officer

The attached manuscript entitled "An Analysis of Air Pollution and its Health Effects: Washington D.C. Metropolitan Area" should be made available through NTIS. The reasons are as follows:

(a) Research results discussed in the attached report merely substantiate earlier findings published in EPA publication No. 600/5-77-010. The publication is titled "Air Pollution and Health in Washington D.C.: Some Acute Health Effects of Air Pollution in the Washington Metropolitan Area." The subject publication is a follow on to 600/5-77-010, and reports on the analysis of additional data.

(b) The research results are not significant from an environmental health standpoint, resulting in a limited, interested audience.

(c) Year end money is not available for publishing this manuscript.

DISCLAIMER

This report has been reviewed by the Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that its contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The methods, results, and conclusions found in this study do not necessarily reflect the opinions of the sponsoring agencies or the organizations who provide data. Specifically, with regard to the data supplied by the Group Health Association (GHA), it is recognized that: (1) the socio-demographic characteristics of the GHA membership may not be representative of the socio-demographic characteristics of the entire metropolitan Washington population; (2) utilization of medical services by the general Washington population; and (3) only within plan utilization is accounted for, i.e., some GHA members may, at times, seek outside medical care which is not recorded in the data.

FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development (ORD) and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This study was initiated by the Washington Environmental Research Center, ORD, Washington, D. C. and completed at the CERL, ORD, Corvallis, Oregon.

ABSTRACT

This study represents an extension of research begun under a contract (No. 68-01-3144) funded jointly by the U.S. Environmental Protection Agency and the U.S. Department of Transportation entitled, "Air Pollution and Health in Washington, D.C.: An Analysis of Some Acute Health Effects of Air Pollution in the Washington Metropolitan Area." In the original study three basic categories of data were analyzed: health information, air quality measurements, and weather factors. Since undertaking that analysis, additional air pollution and weather data became available. This study has attempted to examine the implications on our previous conclusions of analyzing this expanded data base.

The study period was again 1973-74 and focused on the Washington, D.C. Metropolitan Area. Statistical models were formulated to test the hypothesis that air pollution can aggravate the health status of a population and can result in increased utilization of certain types of medical care services. Primary interest was focused on the effects of mobile-source air pollutants, particularly photochemical oxidants. Meteorological conditions as well as other variables thought to influence the consumption of medical services were included in the models as explanatory variables.

The statistical results indicated that air pollution levels had a very limited effect on the health-care utilization of the group practice even after the additional air pollution and meteorological data were examined.

This report is not an official Resources for the Future (RFF) publication since the findings reported herein have not undergone the full critical review accorded RFF studies.

This report was prepared under contract number 68-03-2415 to the U.S. Environmental Protection Agency. This report covers the period from January 1, 1973, to December 31, 1974; and work was completed as of August 1977.

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Several people associated with the Group Health Association must also be acknowledged for their valuable contributions to the study. In particular, Bruce Steinhardt provided many hours of guidance during our initial efforts to analyze the health data. Our original discussions with Goldie Krantz led to this undertaking. Peter Birk then continued this cooperation.

Finally, those associated with this project at the U.S. Environmental Protection Agency, particularly the Project Officer, John Jaksch, should be thanked for valuable comments and assistance throughout the endeavor.

SECTION I

INTRODUCTION

BACKGROUND

This study represents an extension of research begun under a contract (No. 68-01-3144) funded jointly by the U.S. Environmental Protection Agency and the U.S. Department of Transportation entitled, "Air Pollution and Health in Washington, D.C.: An Analysis of Some Acute Health Effects of Air Pollution in the Washington Metropolitan Area."1/ In the original study three basic categories of data were analyzed: health information, air quality measurements, and weather factors. Since undertaking that analysis, additional air pollution and weather data have become available. It is the purpose of this study to examine the implications on our previous conclusions of analyzing this expanded data base.

Under the previous contract we assessed some acute health effects of air pollution in the Washington, D.C. Metropolitan Area. Specifically, the investigation tested the hypothesis that air pollution can aggravate the health status of an exposed population and can result in increased utilization of certain types of medical care services.

The study period was 1973 and 1974. Statistical models were formulated explaining outpatient health-care utilization at the Group Health Association (GHA), a group practice medical care plan. Primary interest was focused on the effects of mobile-source related air pollutants including carbon monoxide, nitrogen dioxide, non-methane hydrocarbons, and photochemical oxidants. In addition, readings on sulfur dioxide levels were available and these data were analyzed using similar methods.2/ Meteorological conditions, as well as other variables thought to influence the consumption of medical services, were included in the models as explanatory variables. The statistical results indicated that air pollution levels had a very limited effect on the health-care utilization of the group practice.

Specifically, an analysis of the data for 1973 did not indicate a significant relationship between photochemical oxidant readings (as measured by the maximum one-hour average) on any given day and the number of unscheduled visits on that day to three of the four departments (for

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1/ See Seskin [4].

2/ Air pollution exposures were represented by readings of ambient air pollution levels monitored at stations in the Washington, D.C. area. While individual exposure data would have been preferred, lack of information on resident and work locations made geographical assignment of air pollution exposures impossible.

which we analyzed data). These included the urgent visit clinic and the internal medicine and pediatric departments. The only exception was for unscheduled visits to the ophthalmology department. Here a suggestive relationship between oxidant levels and unscheduled visits was noted for further investigation.

We then examined the 1974 data in an effort to replicate the 1973 findings. In general, the results were comparable to those for 1973. Again, a positive and statistically significant relationship was exhibited between the oxidant readings and unscheduled visits to the ophthalmology department. In addition, a suggestive relationship between oxidant levels and utilization of the urgent visit clinic was seen. This relationship was further supported by the results of an analysis involving oxidant pollution data monitored at another station. Finally, for 1974 oxidant data from one of the monitoring stations, a positive and statistically significant association was seen with unscheduled visits to the pediatric department. This relationship, however, did not hold when oxidant data from the other monitoring station were substituted.

Looking at both the 1973 and 1974 results together, the magnitude of the association between unscheduled visits to the ophthalmology department and photochemical oxidant levels indicated that a 10 percent decrease in oxidant levels was related to between a 1.1 and 4.3 percent decrease in unscheduled utilization of the ophthalmology department. The statistically significant 1974 result pertaining to the urgent visit clinic indicated that a 10 percent decrease in oxidant levels was related to a 0.5 percent decrease in urgent visits. The single positive and statistically significant 1974 result pertaining to pediatric visits indicated that a 10 percent decrease in oxidant levels was related to a 0.9 percent decrease in unscheduled pediatric visits. These somewhat mixed findings warranted further investigation.

Thus, we performed statistical analyses in an effort to uncover lag or episodic effects of the air pollution levels on the health care utilization. No such effects were found. Next, we investigated the effects of three other air pollutants related primarily to mobile sources (non-methane hydrocarbons, nitrogen dioxide, and carbon monoxide) and one air pollutant primarily related to stationary sources (sulfur dioxide).

We did not uncover any consistently significant relationship between unscheduled utilization of any department and the levels of non-methane hydrocarbons or the levels of nitrogen dioxide during 1973. Unfortunately, 1974 data on these two air pollutants were not satisfactory to permit a replication of these analyses.

Our empirical results involving carbon monoxide did suggest an association between unscheduled utilization of the ophthalmology department and, to a lesser extent, unscheduled utilization of the pediatric department during 1973. However, each result held for only one of the two monitoring stations providing air pollution data. Furthermore, the significant and positive associations between carbon monoxide levels and department utilization were not found using 1974 data.

Two monitoring stations provided sufficient sulfur dioxide data in 1973 to permit separate analyses. The findings from these analyses indicated two positive and statistically significant associations: one between sulfur dioxide levels and unscheduled visits to the internal medicine department, and the other between sulfur dioxide levels and unscheduled visits to the ophthalmology department. Neither association was significant when air pollution data from the other monitoring station were substituted. Furthermore, the associations failed to hold when 1974 data were analyzed.

Table 1.1 presents a summary of the positive and significant associations between the unscheduled department visits to the Washington group practice and levels of individual air pollutants. Specifically, it displays the estimated percentage reductions in unscheduled visits associated with 10 percent reductions in the relevant air pollution measure.

Since there have been a number of studies suggesting the importance of interactions between air pollutants and their combined effects on health, we examined the possibility of synergistic effects. In particular, we concentrated on synergistic effects of oxidants in combination with nitrogen dioxide, sulfur dioxide, and carbon monoxide. No evidence of interactive effects was found.

We then examined the effects of two additional weather variables, a measure of precipitation and a measure of temperature change. Predominant interest lay in the effects that including these variables had on the magnitude and significance of the coefficients associated with the air pollution variables. Secondary interest was focused on the influence of the specific weather variables on department utilization. In most cases the inclusion and substitution of particular weather variables did not greatly affect the magnitude and significance of the coefficients of the air pollution variables. The only notable exception occurred when the variable representing temperature change was substituted for the average temperature variable. In this case, the air pollution coefficient displayed mixed effects. This was primarily attributed to the relatively high correlation of average temperature with certain air pollution variables.

In general, the weather variables did not exhibit important relationships with unscheduled department utilization. However, in several cases, temperature change (as measured by the difference between the maximum daily temperature and the minimum daily temperature) was positively and significantly related to the utilization data. This was especially true for the pediatric visits.

The next analysis we undertook was a comparison of the results just discussed with those based on an analysis of Metro Transit Employees (Metro). Because of small sample sizes, we examined total department visits rather than only unscheduled department visits. In general, the results based on the Metro sample did not display consistently significant associations between visits to the clinic departments and air

TABLE 1.1. ESTIMATED PERCENTAGE CHANGE IN UNSCHEDULED VISITS

10 percent change in Air Pollutant (monitoring station, year)	Percent Change in Unscheduled Visits to:[a]			
	Pediatrics department	Internal medicine department	Ophthalmology department	Urgent visit clinic
Photochemical Oxidants[b]				
(CAMP, 1973)			1.1%*	
(CAMP, 1974)	0.9%*		4.3%****	
(C.P., 1974)				0.5%*
Carbon Monoxide				
(CAMP, 1973)			1.5%****	
(D.C., 1973)	0.6%*			
Sulfur Dioxide				
(D.C., 1973)		0.6%*		
(ACS, 1973)			1.1%*	

[a]Significance levels: *, 10 percent; **, 5 percent; ***, 2 percent; ****, 1 percent.

[b]Abbreviations: C.P., Cleveland Park; D.C., D.C. General Hospital; ACS, American Chemical Society.

pollution levels. The only exception was the association exhibited between visits by the Metro employees to the ophthalmology department and photochemical oxidant levels during 1974. We concluded that the findings for the Metro sample were not at great variance with the previous results based on unscheduled visitation by the total sample. However, given the limited data and the difficulties associated with analyzing small samples, we cautioned against overinterpretation of this conclusion.

Finally, we examined the findings pertaining to the data from a smaller GHA facility located in Takoma Park. In general, the associations involving the Takoma Park data were weaker than the associations based on the data from the main facility. Several possible explanations for this were presented. Since Takoma Park had no ophthalmology department and since the sample sizes at Takoma Park were considerably smaller than those pertaining to the Pennsylvania Avenue clinic, we do not feel that these results negated our previous findings.

AN OVERVIEW OF THE RESEARCH

The study area of this research is the Washington, D.C. Metropolitan Area during the period 1973 and 1974. The nation's capital is of particular interest because mobile-source air pollution is a dominant factor in Washington; whereas, stationary sources (e.g., power plants) are the chief contributors of air pollution in other major eastern seabord cities. In view of the controversies surrounding environmental legislation of regulations on mobile-source emissions, the results for the Washington area may be extremely significant for policy purposes.

The data for this study came from several sources. The Group Health Association, a prepaid group practice medical care plan with approximately 100,000 members, provided the health data. The air pollution data used in the research came from the Government of the District of Columbia, Department of Environmental Services and the Maryland Department of Health and Mental Hygiene.3/ Finally, the meteorological data were provided by the National Climatic Center.

Section II presents a summary of our findings. In Section III we shall discuss the expanded air pollution and meteorological data base. Finally, Section IV presents the empirical results.

3/ Although the Washington, D.C. Metropolitan Area includes certain counties in northern Virginia, no satisfactory air pollution data were available for these areas.

SECTION II

SUMMARY OF FINDINGS

We have analyzed health care utilization, air pollution, and weather data in an effort to test the null hypothesis that there is no significant association between air pollution levels in metropolitan Washington, D.C. and health effects.

First, we examined the relationship between recorded levels of a specific air pollutant across monitoring stations in metropolitan Washington, D.C., as well as the associations between monitored levels of different air pollutants at a given station. In addition, the relationships between air pollution levels, weather factors, and the occurrence of weekends was investigated.

During the time period under investigation, the national primary and secondary ambient air quality standards for the air pollutants we examined were occasionally exceeded at individual monitoring stations. However, in general, the average readings (on an annual basis) of the air pollutants were below the standards. The major exception was non-methane hydrocarbons which exhibited annual averages in excess of the standards. In addition, the standard deviations of the air pollution series indicated widespread variation in the monitored levels over time.

The degree of correlation across monitoring stations of a given air pollutant depended on which air pollutant was under consideration. For example, photochemical oxidant levels across stations were more highly correlated than levels of any of the remaining air pollutants examined. Monitored levels of non-methane hydrocarbons, nitrogen dioxide, and nitric oxide exhibited relatively low correlations across stations. Correlations of carbon monoxide levels monitored at different stations exhibited relatively close associations. This was noted with interest since readings of carbon monoxide tend to be highly dependent on the specific location of the monitor. The two measures of sulfur dioxide levels also tended to rise and fall together throughout the metropolitan area. Finally, it was noted that the limited data available pertaining to soiling indicated that levels of this air pollutant exhibited consistent patterns at different monitoring stations over time.

For many of the air pollutants there was evidence that associated specific monitoring locations with high or low readings. For example, relative to the other stations, low levels of oxidants were monitored at Silver Spring during both 1973 and 1974. With regard to non-methane hydrocarbons, the monitoring stations did not exhibit a consistent pattern. For nitrogen dioxide, relative to the other stations, average readings monitored at Bethesda were low and average readings monitored at Silver Spring were high. (Maximum values during both 1973 and 1974 were reported at Suitland.) At the same time, relative to other stations, Suitland reported low average readings of nitric oxide, while Silver Spring reported

high average readings. (Bethesda reported the maximum readings of nitric oxide.) During 1973 and 1974, relative to the other stations, Bethesda recorded low carbon monoxide levels, while Gaithersburg recorded high levels.1/ For both measures of sulfur dioxide, relative to the other stations, low readings were monitored at Suitland and high readings were monitored at stations in the District of Columbia. Finally, for soiling, the lowest readings were recorded at the Rockville monitoring station and the highest readings were recorded at the Silver Spring monitoring station.2/

In looking at the levels of different air pollutants monitored at a given station, some consistent patterns were seen. For example, readings of photochemical oxidants were negatively correlated with readings of the other air pollutants, although the magnitudes of the correlations were usually small. At the same time, most of the other air pollutants exhibited positive correlations with each other. (The magnitudes of these latter relationships exhibited considerable variation.)

At those stations monitoring both non-methane hydrocarbons and carbon monoxide, a close positive association was often observed. This might be expected since in the Washington Metropolitan Area levels of both of these air pollutants are primarily attributed to mobile-source emissions. A consistent association was also seen between levels of carbon monoxide and the soiling index at stations monitoring both of these air pollution measures.3/ The other noticeably consistent relationships between air pollutants involved both measures of sulfur dioxide and the soiling index. We suggested that this may have been due to the fact that these air pollutants are generally attributed to stationary sources; hence, on days when such emitters represent important pollution sources, both types of air pollutants may be involved.

In examining the relationships between the monitored levels of the various air pollutants and the two weather variables, average daily temperature and average daily wind speed, several consistent associations were also observed. The most apparent of these was the positive relationships between photochemical oxidant levels and average daily temperature; the magnitude of the correlations was usually in excess of .5. This association, of course, was not surprising since the formation of oxidants depends on a photochemical process. However, it did suggest the difficulties involved in disentangling the independent effects on health status of temperature and oxidant levels.

1/ This result was somewhat surprising since Gaithersburg is an outlying suburb of metropolitan Washington and one would not expect as dense a concentration of mobile-source emitters. However, placement of the monitoring device can be critical in measuring carbon monoxide and this may explain these findings.

2/ We are unaware of point-source emitters in the areas that would give rise to this distribution of ambient concentrations.

3/ We suggested the possibility that significant particulate emissions from automobiles could have led to this association, but we had no way of confirming this.

With regard to average daily wind speed, it was noted that this variable was usually negatively related to monitored levels of the air pollutants examined. This result was also anticipated since wind presumably disperses concentrations of air pollutants that build up in the atmosphere. The negative relationship was most apparent with respect to the soiling index variable. Since the index is a measure of particulate matter this may have indicated that the particles were being dissipated by the wind.

Finally, with regard to the effects of weekends we noted that although Saturdays and Sundays were generally negatively associated with monitored air pollution levels, the magnitudes of these associations were relatively small. A number of explanations for this can be given. First, in those cases where mobile-sources are thought to be the important pollution emitters, weekend traffic may compensate for commuting traffic during the week. Alternatively, there may be other sources of the observed air pollution levels (both on weekdays and weekends). A third possibility is that the air pollutants may be sufficiently persistent (perhaps because of meteorological factors) that a distinct weekend effect does not take place.

Thus, we concluded that the air pollution profile in the Washington Metropolitan Area (as represented by the District of Columbia and Maryland data) exhibited some degree of uniformity. The implication of this observation was that using only a few air pollution monitoring stations may not seriously bias the measurement of out-of-doors exposure of the "average" Washingtonian. This conclusion seemed especially true with regard to photochemical oxidants, the air pollutant of primary interest.4/

Next we presented the empirical results of analyzing the air pollution, meteorological, and health data.5/ Regression results were discussed in which these data were analyzed by specific air pollutant.

With respect to photochemical oxidants, the regression results were generally similar to those of the earlier study. As before, the most consistent, positive and statistically significant association was between oxidant levels and unscheduled visits to the ophthalmology department. This was particularly true for the 1973 data; the 1974 data were somewhat less consistent. The magnitude of the association based on the 1973 results indicated that a 10 percent decrease in oxidant levels was related to between a 1.0 and 1.5 percent decrease in unscheduled ophthalmologic visits. In addition, there was a suggestive association between photochemical oxidant levels and 1974 urgent clinic visits; however, both the statistical significance and the magnitude of the association were smaller than the associations pertaining to the ophthalmology department. Furthermore, we did not have 1973 data to test these findings for consistency between two years.

4/ However, we must again note that since data for northern Virginia were unavailable for analysis, this conclusion should not be overinterpreted.

5/ Again, we note that air pollution exposure was represented by readings of ambient air pollution levels. (See Section I, fn. 2.)

The results for non-methane hydrocarbons and nitrogen dioxide were also similar to the earlier study based on the more limited air pollution data. There was no consistent evidence of a positive and statistically significant association between levels of either of these two air pollutants and unscheduled department utilization.

In our earlier work, no data were available on nitric oxide levels in the Washington Metropolitan Area. When such data were analyzed in this study, there was no evidence of consistent, positive associations between nitric oxide levels and unscheduled department utilization. It was noted that this air pollutant is primarily of interest in its role as a precursor to the formation of photochemical oxidants. Since it is thought to be relatively harmless by itself, our findings were not surprising.

With regard to the analysis of carbon monoxide levels, some consistency during single years was displayed between elevated levels of this air pollutant and unscheduled department utilization. However, in each case, replications based on data from a second year failed to demonstrate similar associations. Furthermore, even in those instances where consistency for a single year was observed, the magnitudes of the relationships were relatively small.

Two measures of sulfur dioxide were also examined. As before, isolated positive and statistically significant associations between levels of this air pollutant and unscheduled department utilization were noted. However, replications again failed to confirm these relationships. Furthermore, reanalysis of the 1973 and 1974 sulfur dioxide statistics could not explain these disparate findings.

Finally, data were analyzed on readings of a soiling index in conjunction with unscheduled department utilization. These data were unavailable for the earlier research; hence, no comparison could be made. Nevertheless, the results of the analyses were suggestive of possible associations between levels of soiling and unscheduled department utilization. However, the associations were sufficiently weak that we did not emphasize their magnitudes.

Following these analyses, we investigated the effects of including and substituting additional meteorological variables that included measures of relative humidity. As in our earlier study, alterations in the specification did not have a great effect on the previously estimated associations. Furthermore, the climatic variables themselves did not seem to be important explanatory variables of department utilization.

SECTION III

THE EXPANDED AIR POLLUTION AND METEOROLOGICAL DATA BASE

THE AIR POLLUTION DATA

The expanded air pollution data base used in this research came from the state of Maryland Department of Health and Mental Hygiene. The specific air pollutant measurements that were available and characteristics of the monitored levels will be discussed below. The order of discussion is by pollutant: photochemical oxidants, non-methane hydrocarbons, nitrogen dioxide, nitric oxide, carbon monoxide, sulfur dioxide, and soiling index.

Photochemical Oxidants

In addition to the photochemical oxidant data monitored at the Continuous Air Monitoring Program (CAMP) station in downtown Washington, oxidant readings were also available from four additional monitoring stations in Maryland for 1973: Bethesda, Gaithersburg, Silver Spring, and Suitland. (See Figure 3.1 for the approximate locations of these stations.1/) In each case, the maximum one-hour readings were recorded.

Table 3.1 shows the mean and maximum values of the daily series of maximum one-hour readings monitored at each station.2/ In addition, we have included the standard deviation of each series as an indication of the variation in the monitored levels. As can be seen, the annual mean for Silver Spring was the lowest of the five stations (0.033 ppm), while that for Bethesda was the highest (0.052 ppm). At the same time, the highest one-hour average was recorded at Suitland (0.210 ppm). To put these readings in perspective one should note that the primary and secondary national standard is set at 0.08 ppm maximum one-hour average. In addition, the standard deviations of the series indicate that there was widespread variation in each of the series of readings.3/

Below the table, Figure 3.2 displays the simple correlations between the photochemical oxidant levels recorded at the five monitoring stations. All of the correlations are highly significant ranging from .586 for the Silver Spring-Suitland correlation to .810 for the Bethesda-Gaithersburg

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1/ It should be noted that the Rockville station did not monitor sufficient data to enable an analysis of photochemical oxidants. Appendix A presents the air pollution profile of the Maryland stations. In the analyses that follow only those monitoring stations having sufficient data on the specific air pollutant in question are included. This also applies to the stations located in the District of Columbia.

2/ The minimum values are not shown on the tables, since they were generally equal to zero.

3/ For example, if one assumed that the air pollution readings had the characteristics of a normal distribution, approximately two-thirds of the readings would occur between plus or minus one standard deviation about the mean.

Figure 3.1. Location of Maryland Monitoring Stations.

TABLE 3.1. 1973 OXIDANT READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	.048	.180	.032
Bethesda (B)	.052	.190	.039
Gaithersburg (G)	.042	.130	.023
Silver Spring (SS)	.033	.130	.025
Suitland (Suit)	.045	.210	.034

[a] All figures in parts per million.

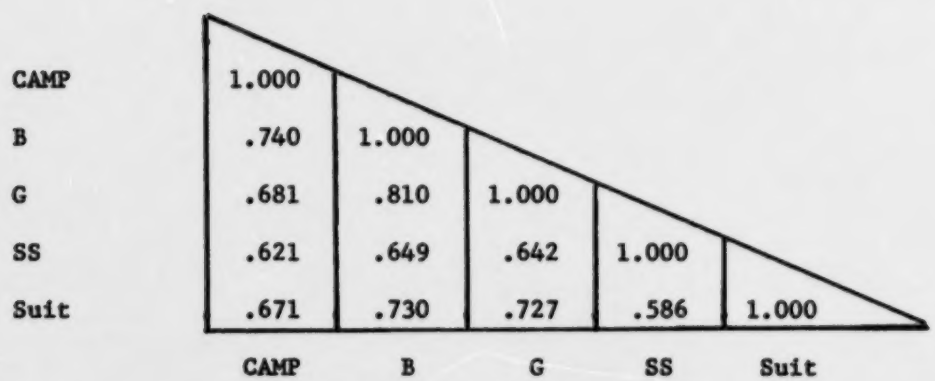


Figure 3.2. Correlations between oxidant readings (1973).

correction. It is noteworthy that there is a close relationship between monitored levels of photochemical oxidants at the various stations around the metropolitan area.

Table 3.2 displays similar information to that in Table 3.1 for the 1974 oxidant data. Again, Silver Spring reported the lowest annual mean (0.033 ppm), while this time the highest was recorded at Suitland (0.058 ppm). The Cleveland Park station (CP) in the District reported the highest reading (0.220 ppm). Considerable variation in the readings over time is indicated by the standard deviations of each series, although Figure 3.3, which reports the simple correlations, reveals close associations between station readings on a day-to-day basis.

Non-methane Hydrocarbons

In addition to the non-methane hydrocarbon data monitored at the CAMP station, such data were also available from three stations in Maryland for 1973: Bethesda, Silver Spring, and Suitland. In each case, three-hour averages (6:00 a.m. to 9:00 a.m.) were recorded.

Table 3.3 shows the mean, maximum, and standard deviation of the daily series of readings monitored at each of the four stations. As can be seen, the annual mean for Bethesda was lowest of the four stations (0.266 ppm), while that for the CAMP station was highest (0.564 ppm). However, the maximum three-hour average was recorded at Suitland (8.067 ppm). To put these levels into perspective, one should note that the primary and secondary national standard (not to be exceeded more than once per year) is set at 0.24 ppm based on an annual average of daily three-hour averages. Clearly, the levels of non-methane hydrocarbons in the metropolitan Washington area frequently exceeded this standard (see Appendix A). At the same time, the relatively large standard deviations again indicate widespread variation in the monitored readings.

Figure 3.4, below the table, reports the simple correlations between the monitored levels of non-methane hydrocarbons recorded at the four stations.4/ It can be seen that the correlations are substantially smaller than those pertaining to monitored oxidant levels discussed above. They range from .047 for CAMP-Bethesda to .445 for Bethesda-Silver Spring.

Table 3.4 presents the statistics for the 1974 non-methane hydrocarbon data. As can be seen, the CAMP station is excluded. It did not monitor sufficient data to permit analyses. The data from the three Maryland stations were similar to those for 1973. The correlation matrix (Figure 3.5) indicates even smaller associations than those pertaining to the 1973 non-methane hydrocarbon data. Note that the Bethesda-Silver Spring correlation was small and negative (-.012).

4/ Correlations between the monitored levels of different air pollutants at a given station are discussed below.

TABLE 3.2. 1974 OXIDANT READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	.038	.150	.027
D.C. (CP)	.044	.220	.033
Bethesda (B)	.048	.140	.030
Gaithersburg (G)	.037	.150	.025
Silver Spring (SS)	.033	.140	.025
Suitland (Suit)	.058	.180	.033

[a] All figures in parts per million.

	CAMP	CP	B	G	SS	Suit
CAMP	1.000					
CP	.629	1.000				
B	.688	.760	1.000			
G	.550	.736	.795	1.000		
SS	.529	.742	.705	.577	1.000	
Suit	.649	.683	.791	.669	.705	1.000

Figure 3.3. Correlations between oxidant readings (1974).

TABLE 3.3. 1973 NON-METHANE HYDROCARBON READINGS
(THREE-HOUR AVERAGES 6:00 AM - 9:00 AM)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	.564	4.100	.542
Bethesda (B)	.266	2.033	.346
Silver Spring (SS)	.333	3.433	.461
Suitland (Suit)	.322	8.067	.642

a/ All figures in parts per million.

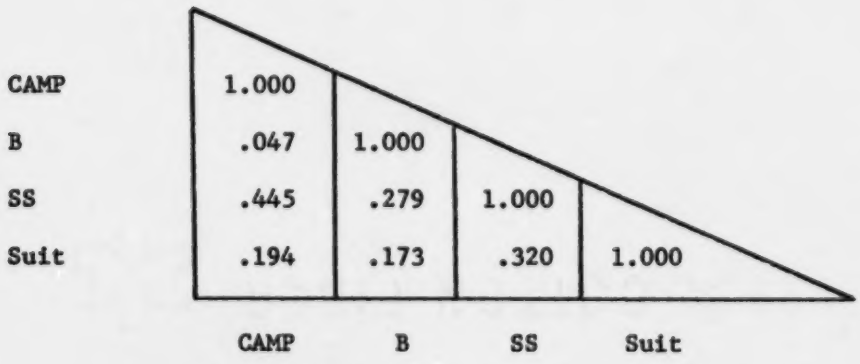


Figure 3.4. Correlations between non-methane hydrocarbon readings (1973).

TABLE 3.4. 1974 NON-METHANE HYDROCARBON READINGS
(THREE-HOUR AVERAGES 6:00 AM - 9:00 AM)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
Bethesda (B)	.296	3.433	.383
Silver Spring (SS)	.375	3.233	.430
Suitland (Suit)	.309	2.233	.315

a/ All figures in parts per million.

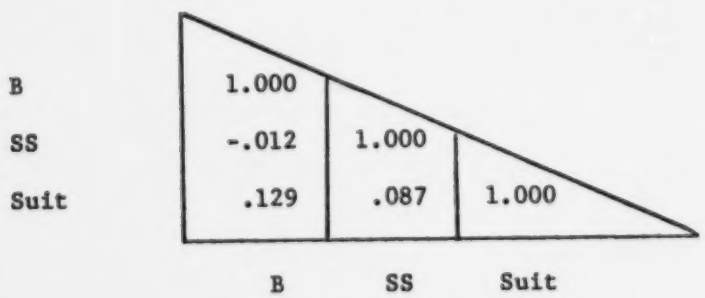


Figure 3.5. Correlations between non-methane hydrocarbon readings (1974).

Nitrogen Dioxide

The three Maryland stations in Bethesda, Silver Spring, and Suitland, again provided additional 1973 data to those available from the CAMP station for nitrogen dioxide. In each case 24-hour averages were recorded and they indicated (see Table 3.5) that the mean nitrogen dioxide levels in the area were approximately at or below the national primary and secondary standard (0.05 ppm). Silver Spring had the highest mean (0.051 ppm), although Suitland reported the maximum 24-hour average (0.210 ppm).

Figure 3.6, below the table, indicates that the correlations between nitrogen dioxide readings at the four stations vary considerably. The smallest was for Silver Spring-Suitland (.135) and the largest was for CAMP-Silver Spring (.533).

Again, only the Maryland stations provided sufficient 1974 data for analysis (Table 3.6). Again, Silver Spring reported the highest mean level (0.058 ppm), and Suitland the maximum 24-hour average (0.240 ppm). The 1974 correlations between station readings of nitrogen dioxide (Figure 3.7) were lower than those pertaining to photochemical oxidants (Figure 3.3), but higher than those pertaining to non-methane hydrocarbons (Figure 3.5).

Nitric Oxide

Although there are no national standards for nitric oxide, 5/ readings of this air pollutant were available from three monitoring stations in Maryland: Bethesda, Silver Spring, and Suitland for both 1973 and 1974 (see Tables 3.7 and 3.8). In each case, maximum one-hour averages were reported.

As can be seen from the tables, the levels recorded were considerably higher in 1973 than in 1974, although the standard deviations indicate that there was considerable variation in both years. The lowest annual mean was for Bethesda in 1974 (0.062 ppm) and the highest was for Silver Spring in 1973 (0.254 ppm). The maximum reading was recorded at Bethesda in 1973 (1.000 ppm). 6/

5/ Nitric oxide itself is a relatively harmless gas, however, it plays a major role in the formation of photochemical oxidants. Specifically, nitric oxide oxidizes into nitrogen dioxide at high concentrations or in the presence of hydrocarbons and sunlight. This nitrogen dioxide then reacts with hydrocarbons and sunlight to produce nitric oxide again and ozone; the cycle then repeats.

6/ To put these readings in perspective we note the following 1972 annual statistics on nitric oxide for three cities in southern California:

City	Mean	Maximum
Anaheim	.206	.850
Azusa	.101	.640
Los Angeles (downtown)	.289	.920

Source: [1].

TABLE 3.5. 1973 NITROGEN DIOXIDE READINGS (24-HOUR AVERAGES)[a]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	.045	.101	.015
Bethesda (B)	.041	.127	.022
Silver Spring (SS)	.051	.200	.027
Suitland (Suit)	.049	.210	.026

[a] All figures in parts per million.

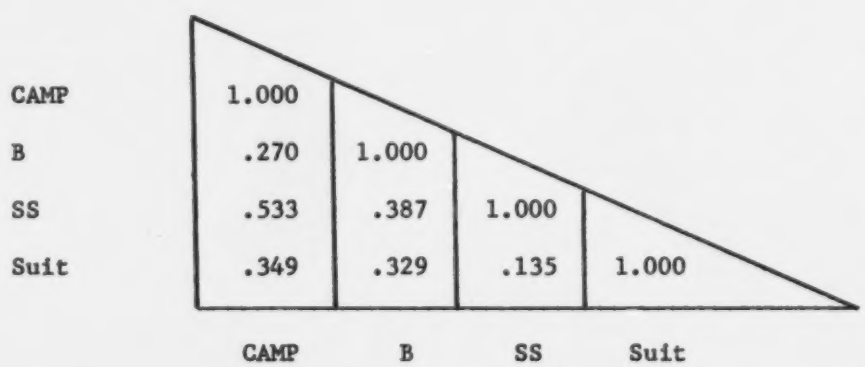


Figure 3.6. Correlations between nitrogen dioxide readings (1973).

TABLE 3.6. 1974 NITROGEN DIOXIDE READINGS (24-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
Bethesda (B)	.034	.121	.020
Silver Spring (SS)	.058	.156	.029
Suitland (Suit)	.048	.240	.034

a/ All figures in parts per million.

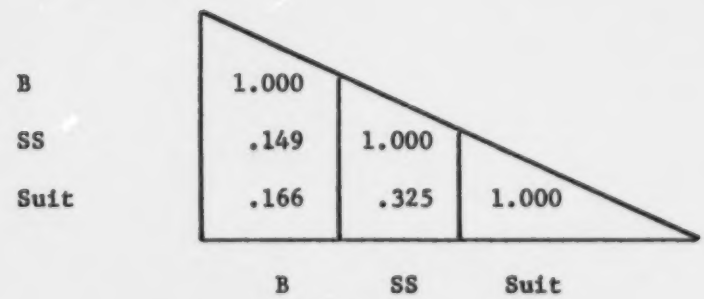


Figure 3.7. Correlations between nitrogen dioxide readings (1974).

TABLE 3.7. 1973 NITRIC OXIDE READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a]

Monitoring Station	Mean	Maximum	Standard Deviation
Bethesda (B)	.217	1.000	.351
Silver Spring (SS)	.254	.800	.202
Suitland (Suit)	.108	.640	.109

[a] All figures in parts per million.

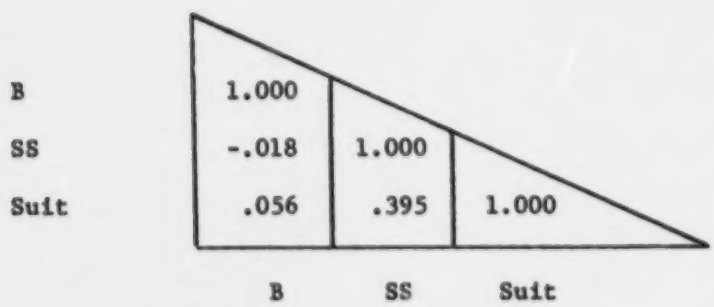


Figure 3.8. Correlations between nitric oxide readings (1973).

TABLE 3.8. 1974 NITRIC OXIDE READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
Bethesda (B)	.062	.690	.085
Silver Spring (SS)	.159	.480	.101
Suitland (Suit)	.066	.360	.072

a/ All figures in parts per million.

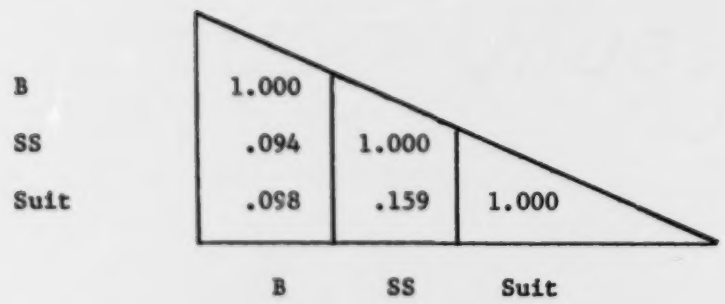


Figure 3.9. Correlations between nitric oxide readings (1974).

The correlation matrices below each table (Figures 3.8 and 3.9) indicate that the simple correlations between station readings were relatively small. The only exception was the 1973 Silver Spring-Suitland correlation (.395).

Carbon Monoxide

In addition to two monitoring stations in the District of Columbia, the CAMP and the D.C. General Hospital (HOSP) stations, 1973 carbon monoxide data were also available from four Maryland monitoring stations located in Bethesda, Gaithersburg, Silver Spring, and Suitland (Table 3.9). It is apparent from the table that there was a considerable range in the levels recorded at the various stations. The lowest mean value was for Bethesda (2.641 ppm), while the highest was for Gaithersburg (8.106 ppm). At the same time, the maximum value was recorded at the CAMP station (43 ppm), and the lowest was recorded at both Silver Spring and Suitland (24 ppm). These can be compared to the national primary and secondary standard of 35 ppm based on a maximum one-hour average. Despite the fact that it is well known (and consistent with our data) that recorded levels of carbon monoxide exhibit substantial variation, it is interesting that the correlation matrix (Figure 3.10) indicates that levels at different stations went up and down together on a day-to-day basis.

The carbon monoxide data for 1974 followed a similar pattern (Table 3.10). Although the CAMP station did not provide sufficient readings to permit analysis, the remaining stations did. In general, the monitored readings displayed similar means, maximums, and standard deviations to their counterparts for 1973. Furthermore, the correlation matrix pertaining to the 1974 data (Figure 3.11) was also similar to the correlation matrix for the 1973 data.

Sulfur Dioxide

Two monitoring stations in the District and four located in Maryland provided 1973 readings of sulfur dioxide levels. Two types of readings were available from each, one based on maximum one-hour averages and the other based on 24-hour averages. Statistics derived from these data series are reported in Tables 3.11 and 3.12, respectively. As can be seen the mean value of the maximum one-hour averages ranged from 0.012 ppm at Suitland to 0.060 ppm at the American Chemical Society (ACS) in the District. The maximum values of these series ranged from 0.120 ppm at both Rockville and Suitland to 0.320 ppm at the D.C. (HOSP) station. At the same time, the mean values of the data based on 24-hour averages ranged from a low of 0.003 ppm for Suitland to a high of 0.035 ppm for D.C. (HOSP). The maximum values of the 24-hour averages ranged from 0.015 ppm at Suitland to 0.140 ppm at D.C. (ACS). To put these values in perspective, one should note that the primary standard for sulfur dioxide is 0.14 ppm based on a 24-hour average. 7/ The standard deviations indicate considerable variation

7/ There are no national standards for sulfur dioxide based on maximum one-hour averages.

TABLE 3.9. 1973 CARBON MONOXIDE READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	6.947	43.000	5.004
D.C. (HOSP)	6.856	30.000	4.636
Bethesda (B)	2.641	25.000	2.786
Gaithersburg (G)	8.106	38.000	5.719
Silver Spring (SS)	5.327	24.000	3.517
Suitland (Suit)	2.873	24.000	2.648

a/ All figures in parts per million.

	CAMP	HOSP	B	G	SS	Suit
CAMP	1.000					
HOSP	.507	1.000				
B	.488	.470	1.000			
G	.400	.408	.581	1.000		
SS	.375	.361	.623	.463	1.000	
Suit	.484	.470	.539	.369	.314	1.000

Figure 3.10. Correlations between carbon monoxide readings (1973).

TABLE 3.10. 1974 CARBON MONOXIDE READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (HOSP)	6.763	28.000	4.339
Bethesda (B)	2.842	15.000	2.933
Gaithersburg (G)	7.781	43.000	5.890
Silver Spring (SS)	5.291	17.000	3.365
Suitland (Suit)	3.560	21.000	2.900

[a] All figures in parts per million.

	HOSP	B	G	SS	Suit
HOSP	1.000				
B	.318	1.000			
G	.494	.449	1.000		
SS	.382	.522	.482	1.000	
Suit	.248	.268	.311	.498	1.000

Figure 3.11. Correlations between carbon monoxide readings (1974).

TABLE 3.11. 1973 SULFUR DIOXIDE READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (HOSP)	.041	.320	.032
D.C. (ACS)	.060	.222	.038
Bethesda (B)	.024	.210	.030
Rockville (R)	.027	.120	.018
Silver Spring (SS)	.019	.150	.016
Suitland (Suit)	.012	.120	.013

a/ All figures in parts per million.

	HOSP	ACS	B	R	SS	Suit
HOSP	1.000					
ACS	.483	1.000				
B	.127	.254	1.000			
R	.304	.335	.109	1.000		
SS	.408	.435	.297	.349	1.000	
Suit	.351	.135	.045	.173	.280	1.000

Figure 3.12. Correlations between sulfur dioxide readings (1973).

TABLE 3.12. 1973 SULFUR DIOXIDE READINGS (24-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (HOSP)	.035	.134	.022
D.C. (ACS)	.021	.140	.014
Bethesda (B)	.008	.074	.010
Rockville (R)	.013	.065	.011
Silver Spring (SS)	.007	.040	.007
Suitland (Suit)	.003	.015	.004

a/ All readings in parts per million.

	HOSP	ACS	B	R	SS	Suit
HOSP	1.000					
ACS	.383	1.000				
B	.396	.263	1.000			
R	.297	.174	.115	1.000		
SS	.511	.427	.494	.363	1.000	
Suit	.337	.292	.194	.299	.499	1.000

Figure 3.13. Correlations between sulfur dioxide readings (1973).

in the monitored levels at a given station. The matrices pertaining to the 1973 data on sulfur dioxide (Figures 3.12 and 3.13) indicate that the correlations between station readings were slightly smaller than those pertaining to carbon monoxide (see above).

Tables 3.13 and 3.14 present analogous information for the 1974 sulfur dioxide data.8/ In general, the statistics pertaining to the 1974 data based on maximum one-hour averages followed similar patterns to the corresponding 1973 data. The statistics pertaining to the 1974 data based on 24-hour averages were somewhat less consistent with their 1973 counterparts. The correlation matrices pertaining to the 1974 data (Figures 3.14 and 3.15) also exhibited these characteristics.

Soiling Index

Although no data pertaining to particulate matter were available for the District of Columbia, four Maryland stations provided soiling index data. Table 3.15 shows the statistics pertaining to the readings recorded at these stations. As can be seen the mean levels ranged from 0.443 coh at Rockville to 1.192 coh at Silver Spring.9/ These stations also recorded the low and high values of the maximum levels, 3.110 coh and 5.700 coh, respectively. The standard deviations show that there was considerable variation in the readings at each station, while the correlation matrix (Figure 3.16) indicates that the levels across the four stations followed similar patterns over time.

Table 3.16 presents the statistics for the 1974 soiling index data. Again, the lowest mean level was recorded at Rockville (0.572 coh) and the highest at Silver Spring (1.181 coh). In this case, the low and high maximum levels were monitored at Rockville (2.400 coh) and Suitland (8.800 coh), respectively. The correlations between monitored levels across stations (Figure 3.17) indicate relatively close associations between three of the four stations. The exception was the Rockville station.

8/ Note, neither D.C. (HOSP) nor D.C. (ACS) provided sufficient data based on maximum one-hour averages to permit analyses; however, such data were available in 1974 from the D.C. (CAMP) station. In addition, the D.C. (ACS) station did not provide sufficient data based on 24-hour averages to permit analysis.

9/ The abbreviation coh represents the measure of pollution, coefficient of haze. This soiling index is derived by testing the permiability to light of a paper tape that acts as a filter for a given volume of air.

TABLE 3.13. 1974 SULFUR DIOXIDE READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	.037	.220	.031
Bethesda (B)	.020	.100	.019
Rockville (R)	.034	.200	.029
Silver Spring (SS)	.019	.100	.015
Suitland (Suit)	.013	.110	.013

a/ All figures in parts per million.

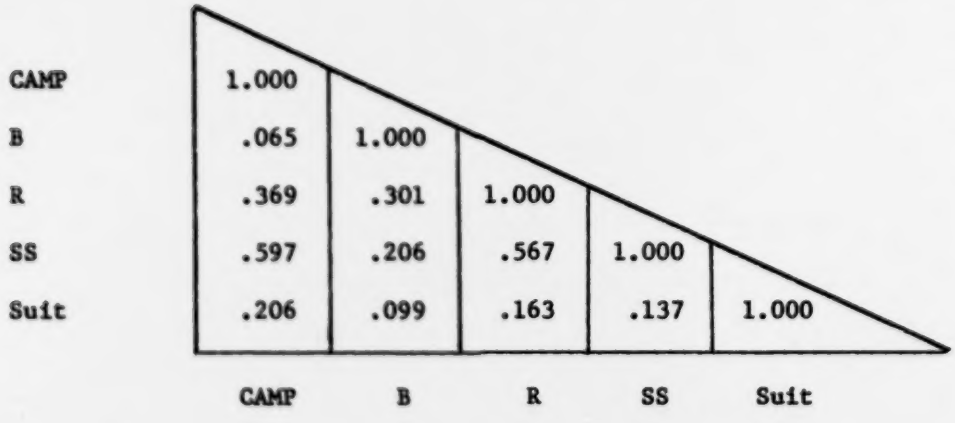


Figure 3.14. Correlations between sulfur dioxide readings (1974).

TABLE 3.14. 1974 SULFUR DIOXIDE READINGS
(24-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
D.C. (CAMP)	.017	.082	.014
D.C. (HOSP)	.014	.062	.009
Bethesda (B)	.006	.039	.007
Rockville (R)	.016	.090	.014
Silver Spring (SS)	.007	.045	.006
Suitland (Suit)	.004	.032	.005

a/ All readings in parts per million.

	CAMP	HOSP	B	R	SS	Suit
CAMP	1.000					
HOSP	.140	1.000				
B	.112	.275	1.000			
R	.399	.108	.439	1.000		
SS	.302	.285	.620	.401	1.000	
Suit	-.079	.363	.235	-.125	.135	1.000

Figure 3.15. Correlations between sulfur dioxide readings (1974).

TABLE 3.15. 1973 SOILING INDEX READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a/]

Monitoring Station	Mean	Maximum	Standard Deviation
Bethesda (B)	.620	3.500	.405
Rockville (R)	.443	3.100	.391
Silver Spring (SS)	1.192	5.700	.770
Suitland (Suit)	.987	4.400	.567

a/ All figures expressed as coefficient of haze (coh) per 1000 linear feet.

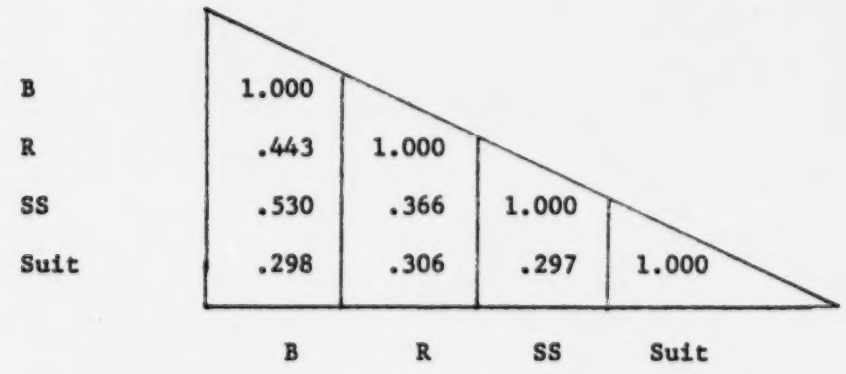


Figure 3.16. Correlations between soiling index readings (1973).

TABLE 3.16. 1974 SOILING INDEX READINGS
(MAXIMUM ONE-HOUR AVERAGES)[a]

Monitoring Station	Mean	Maximum	Standard Deviation
Bethesda (B)	.623	6.900	.686
Rockville (R)	.572	2.400	.385
Silver Spring (SS)	1.181	7.000	.857
Suitland (Suit)	.738	8.800	.766

[a] All figures expressed as coefficient of haze (coh) per 1000 linear feet.

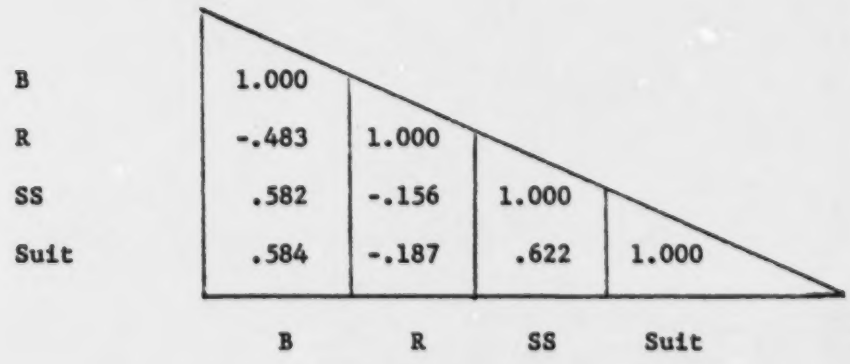


Figure 3.17. Correlations between soiling index readings (1974).

THE METEOROLOGICAL DATA

The expanded meteorological data base used in this research came from the National Climatic Center in Asheville, North Carolina. First we will briefly discuss those variables used in the previous study. Then we will examine the additional variables that were made available. All data were monitored at the station located at Washington National Airport, since it was the most representative weather station in the Washington, D.C. Metropolitan Area.

Variables Used in the Previous Study

The two basic climatological variables used in the previous study were measures of temperature and wind. Specifically, the average daily temperature and the average daily wind speed were included as explanatory variables in the models that were formulated. In addition, a later analysis examined two additional measures, daily precipitation and daily temperature change.10/ The statistics relating to these variables are shown in Table 3.17.

Additional Variables Available for this Study

The meteorological data from the National Climatic Center included three-hourly measures of temperature, humidity, and wind. Since we had previously, analyzed the effect of temperature and wind, our first attention focused on the humidity data. Specifically, we collapsed the three-hourly humidity data into two daily measures: daily average humidity and daily maximum humidity. (The statistics pertaining to these variables are also presented in Table 3.17.)

High temperatures together with high humidity have been associated with both respiratory and cardiovascular problems. One way in which to capture this effect is to define a temperature humidity index (THI). Originally, the primary purpose for developing a THI was to have a simple method of determining the effect of summer conditions in the United States on human comfort.11/ There are various ways to calculate a THI. Jaksch and Stoevener [2] in a study similar to the present one used the following formula:

$$THI = 0.4(T_d + T_w) + 15$$

where T_d is the dry-bulb (air) temperature in degrees Fahrenheit and T_w

10/ The temperature change variable was defined as the difference between the maximum daily temperature and the minimum daily temperature.

11/ See Tromp [5], p. 41.

TABLE 3.17. METEOROLOGICAL VARIABLES USED IN THE STUDY

Variable	Description	Minimum		Mean		Maximum		Standard deviation	
		1973	1974	1973	1974	1973	1974	1973	1974
Av T:	average daily temperature (°F.)	19	26	59.4	58.8	86	85	16.70	15.10
Av Wind:	average daily wind speed (miles per hour)	1.6	2.7	8.4	8.6	22.9	20.4	3.08	3.09
Precip:	total daily precipitation (inches)	0	0	.096	.099	2.88	1.90	.256	.272
Δ T:	temperature difference between daily maximum and daily minimum (°F.)	3	3	18.1	18.8	38	38	6.58	6.41
Av H:	average daily humidity (%)	34.9	38.6	63.6	64.2	89.9	87.0	12.1	11.7
Max H:	maximum daily humidity (%)	46.0	51.0	78.0	78.9	100.0	96.0	11.0	10.5
Av THI:	average daily temperature-humidity index	28.0	34.0	59.4	64.2	80.2	78.7	12.7	10.5
Max THI:	maximum daily temperature-humidity index	31.4	37.8	64.0	68.9	85.0	83.4	12.7	10.7

is the wet-bulb temperature in degrees Fahrenheit.12/

Higher values of the THI indicate increased discomfort to the exposed population. Tromp [5] has reported that empirical studies in the United States have shown that 10 percent of the general population becomes uncomfortable when the THI reaches a value of 70 and that 50 percent of the population becomes uncomfortable when the THI reaches a value of 75. 13/

As can be seen from Table 3.17, the mean of the average daily values of the temperature humidity index was 59.4 in 1973 and 64.2 in 1974. The maximum of the average daily values was 80.2 in 1973 and 78.7 in 1974. Clearly, these statistics suggest that there were a considerable number of days on which it was likely that a large segment of the population experienced discomfort from temperature and humidity conditions in the Washington Metropolitan Area. Furthermore, by looking at the statistics pertaining to the maximum daily THI values, one notes that they are not substantially higher than the average values. This suggests, that the THI was relatively high throughout a given day rather than during an isolated period of that day; hence, the discomfort level associated with a high index reading was probably a day-long phenomenon.

CORRELATIONS BETWEEN AIR POLLUTION, WEATHER, AND WEEKENDS

Before presenting the empirical results relating to the effects of air pollution on our measures of health status, we will discuss the relationships between monitored levels of different air pollutants at a given station. At the same time, we will examine the associations between daily readings of these air pollutants and both daily weather factors and the occurrence of weekends.

In the previous study many of these relationships were examined for the limited air pollution data monitored in the District of Columbia. Here, we will focus on the expanded data available from the Maryland Department of Health and Mental Hygiene for five state monitoring stations. The order of discussion is by specific monitoring station: Bethesda, Gaithersburg, Rockville, Silver Spring, and Suitland. We will be looking for consistency of associations between years at a given station as well as across stations.

12/ Atmospheric humidity can be measured by use of a mercury thermometer with a moistened wick surrounding the mercury reservoir. With adequate ventilation, the wick's temperature is lowered by evaporation to a constant value, which is called the wet-bulb temperature. This, together with air temperature and suitable tables, can be used to determine dew point or relative himidity. (See Licht [3], p. 7.)

13/ See Tromp [5], p. 42.

Bethesda

Figure 3.19 presents the correlations between air pollution levels, weather factors, and weekends for the Bethesda station during 1973. The most noteworthy correlation in the first column is that between oxidant levels (Ox) and daily average temperature (Av T); it was positive and equal to .680. 14/ As expected, days with relatively high average temperature had relatively high oxidant levels. All other correlations with photochemical oxidants were negative, although none was very large in magnitude. It is interesting to note that the two correlations with the weekend days were quite small in magnitude. Apparently, oxidant levels on weekends are not very different from those during the week. Either commuting traffic is replaced by weekend travel or other sources of photochemical oxidants are present in the metropolitan Washington area.15/

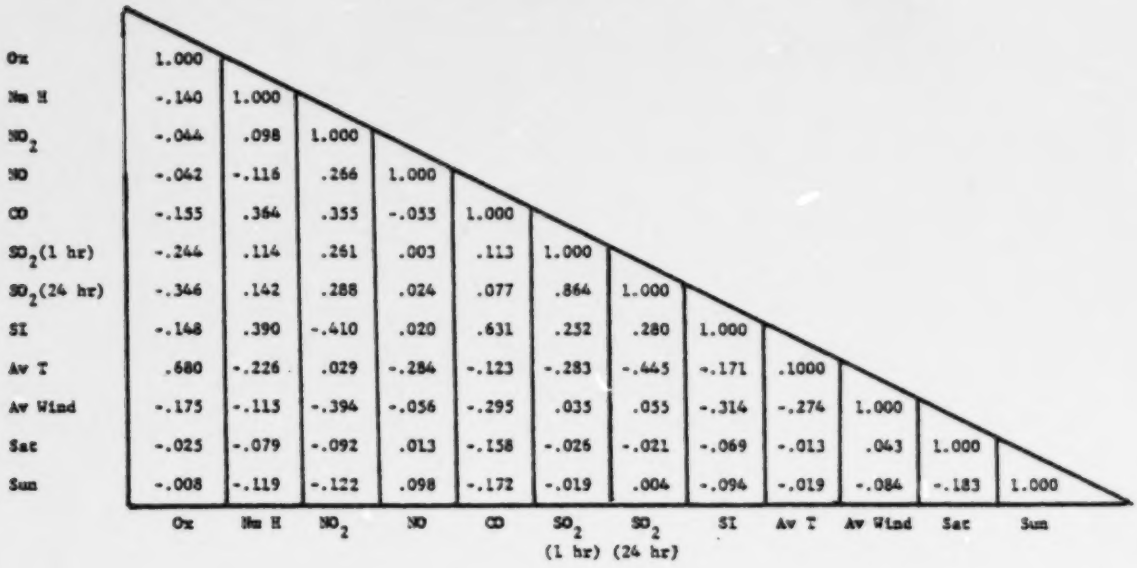
In the second column pertaining to non-methane hydrocarbons (Nm H), one notes positive correlations with carbon monoxide (CO) levels and the soiling index (SI); neither was relatively large in magnitude (.364 and .390, respectively). Correlations of similar magnitude between nitrogen dioxide (NO_2) and several pollution measures can be seen in the third column. No correlation relating to nitric oxide (NO) was of particular interest in the fourth column. With regard to carbon monoxide (CO), we note a relatively large positive correlation with the soiling index (.631) in the fifth column.16/ As expected, the two measures of sulfur dioxide pollution displayed a very high positive correlation (.864). Days with relatively large maximum one-hour averages were generally days in which the twenty-four-hour average levels of sulfur dioxide were also high. In addition, the sulfur dioxide measures were positively related to soiling and negatively related to average temperature.17/ The soiling index column evidenced a noteworthy negative correlation with daily average wind speed (Av Wind). This is not surprising given that wind probably disperses particles in the air. The correlations between the weather factors and weekends were of little interest in themselves; hence, they will not be discussed.

14/ Although the temperature humidity index (THI) is not included in the correlation matrices, separate analyses indicated that it exhibited correlations approximately equal to those between average temperature and the air pollution variables. This is not surprising given its derivation (see above).

15/ There is also the possibility that the air pollution is persistent enough to mask any weekend effects.

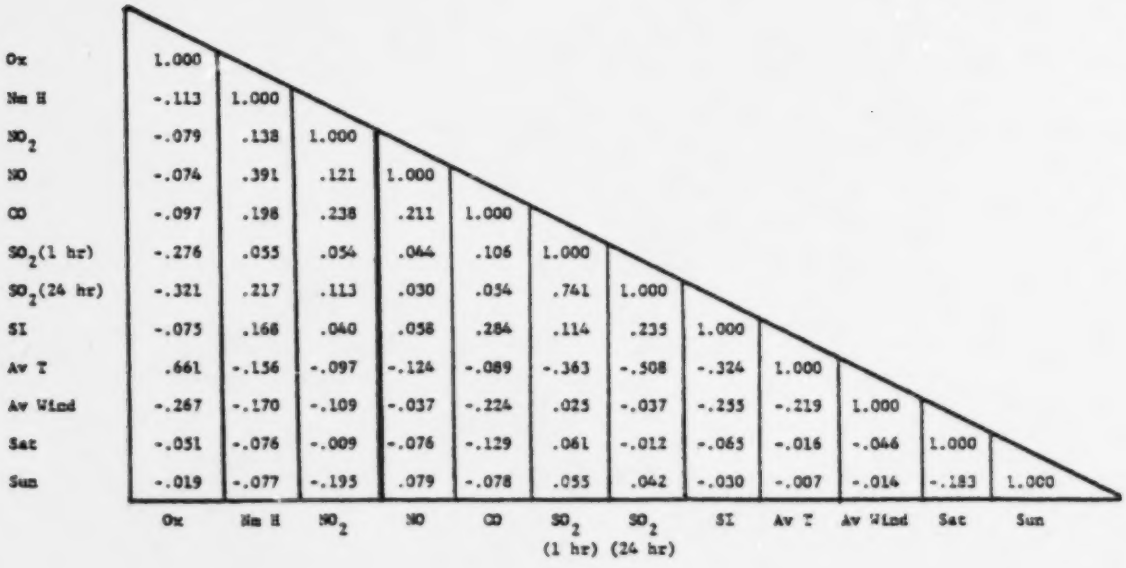
16/ It is possible that significant particulate emissions from automobiles could give rise to this association; however, we have no way of verifying this.

17/ These findings may be due to an association between sulfur dioxide and soiling emitted from stationary sources and to the possibility that such emissions have a seasonal component.



	Ox	Nm H	NO_2	NO	CO	SO_2 (1 hr)	SO_2 (24 hr)	SI	Av T	Av Wind	Sat	Sun
Ox	1.000											
Nm H	-.140	1.000										
NO_2	-.044	.098	1.000									
NO	-.042	-.116	.266	1.000								
CO	-.155	.364	.355	-.033	1.000							
SO_2(1 hr)	-.244	.114	.261	.003	.113	1.000						
SO_2(24 hr)	-.346	.142	.288	.024	.077	.864	1.000					
SI	-.148	.390	-.410	.020	.631	.252	.280	1.000				
Av T	.680	-.226	.029	-.284	-.123	-.283	-.445	-.171	.1000			
Av Wind	-.175	-.115	-.394	-.056	-.295	.035	.055	-.314	-.274	1.000		
Sat	-.025	-.079	-.092	.013	-.158	-.026	-.021	-.069	-.013	.043	1.000	
Sun	-.008	-.119	-.122	.098	-.172	-.019	.004	-.094	-.019	-.084	-.183	1.000

Figure 3.19. Correlations between air pollution levels, weather factors, and weekends (Bethesda - 1973).



	Ox	Nm H	NO_2	NO	CO	SO_2 (1 hr)	SO_2 (24 hr)	SI	Av T	Av Wind	Sat	Sun
Ox	1.000											
Nm H	-.113	1.000										
NO_2	-.079	.138	1.000									
NO	-.074	.391	.121	1.000								
CO	-.097	.198	.238	.211	1.000							
SO_2(1 hr)	-.276	.055	.054	.044	.106	1.000						
SO_2(24 hr)	-.321	.217	.113	.030	.034	.741	1.000					
SI	-.075	.168	.040	.058	.284	.114	.235	1.000				
Av T	.661	-.156	-.097	-.124	-.089	-.363	-.508	-.324	1.000			
Av Wind	-.267	-.170	-.109	-.037	-.224	.025	-.037	-.255	-.219	1.000		
Sat	-.051	-.076	-.009	-.076	-.129	.061	-.012	-.065	-.016	-.046	1.000	
Sun	-.019	-.077	-.195	.079	-.078	.055	.042	-.030	-.007	-.014	-.183	1.000

Figure 3.20. Correlations between air pollution levels, weather factors, and weekends (Bethesda - 1974).

Figure 3.20 presents a similar correlation matrix for Bethesda during 1974. Again, the first column indicates the relatively large, positive correlation (.661) between oxidant levels and average temperature. However, the second column did not evidence the same correlations noted above for non-methane hydrocarbons. (Neither the correlation with carbon monoxide nor the one with the soiling index was of particular interest.) The positive correlation with nitric oxide was noted for further verification. With regard to nitrogen dioxide, none of the correlations in the 1974 data was particularly large, although again the association with carbon monoxide was positive. Again, for nitric oxide, no correlation was of special interest. Although the correlation between carbon monoxide and soiling index was still positive, it had much smaller magnitude in 1974 than in 1973. The columns pertaining to sulfur dioxide again showed positive correlations with soiling and negative correlations with average temperature. The former were smaller and the latter were larger than their 1973 counterparts. The correlation between soiling and average wind speed was again negative for the 1974 data. We will be able to make more confident statements regarding these observed associations after examining the data for the remaining stations.

Gaithersburg

The only two air pollutants monitored at Gaithersburg with sufficient data to permit analysis were photochemical oxidants and carbon monoxide. Figure 3.21 presents the correlations pertaining to data on these two air pollutants, weather factors, and weekends during 1973. The only relatively large correlation in the first column relating to oxidant levels was with average daily temperature (.702). The correlations pertaining to carbon monoxide were all negative. The largest (in magnitude) was with average wind speed indicating that days with relatively high winds had lower levels of carbon monoxide.

Figure 3.22 presents a similar correlation matrix for Gaithersburg during 1974. In this case we see that oxidant levels exhibited a relatively large, positive correlation with average temperature. In the second column we note that carbon monoxide levels were again negatively related to average daily wind speed.

Rockville

Three air pollution measures were available for analysis in Rockville: the maximum one-hour average and the twenty-four-hour average sulfur dioxide readings and the soiling index. (See Figure 3.23.) In addition to the high correlation between the sulfur dioxide readings in the first column, one notes that both measures of sulfur dioxide were also correlated positively with the soiling index. This may be further evidence that both sulfur dioxide and soiling are associated with specific stationary sources of air pollution. All three air pollution measures were negatively related to average temperature and average wind speed. Again, one might conjecture that winter levels of such stationary-source pollutants are likely to be higher than levels during other seasons. Thus, the correlations with temperature are in the expected direction. Furthermore, the dispersion afforded by wind may be the "cause" of the negative correlations.

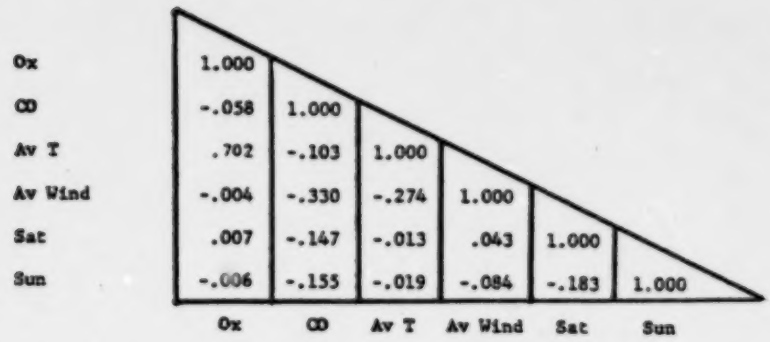


Figure 3.21. Correlations between air pollution levels, weather factors, and weekends (Gaithersburg - 1973).

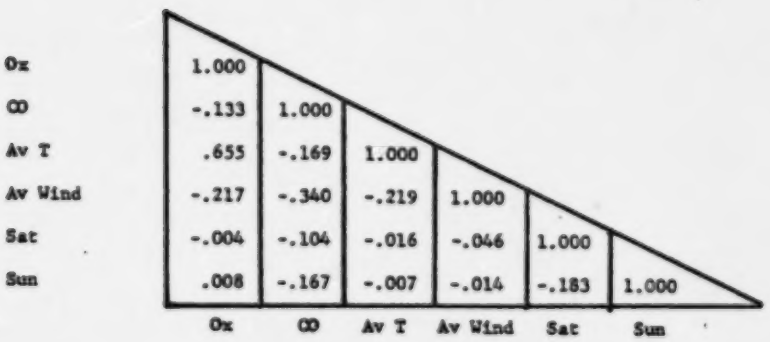
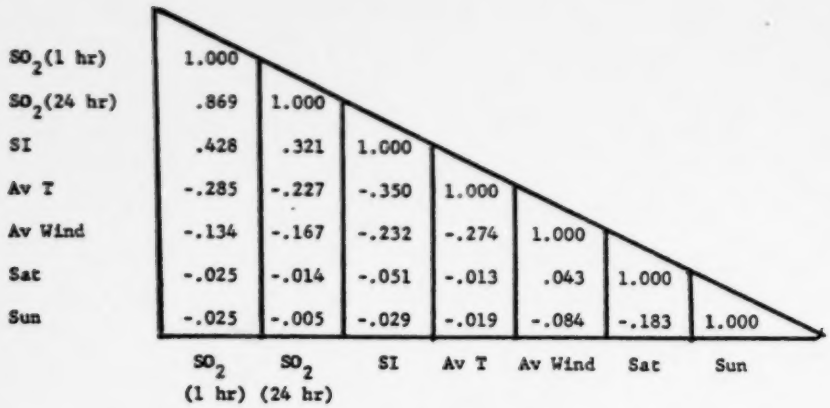
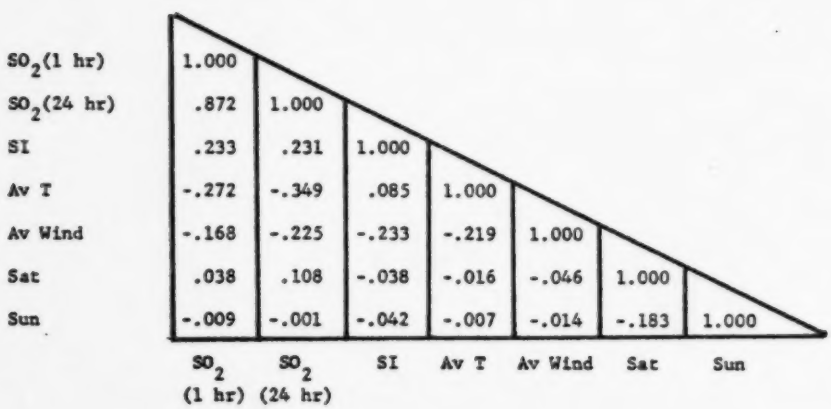


Figure 3.22. Correlations between air pollution levels, weather factors, and weekends (Gaithersburg - 1974).



	SO_2(1 hr)	SO_2(24 hr)	SI	Av T	Av Wind	Sat	Sun
SO_2(1 hr)	1.000						
SO_2(24 hr)	.869	1.000					
SI	.428	.321	1.000				
Av T	-.285	-.227	-.350	1.000			
Av Wind	-.134	-.167	-.232	-.274	1.000		
Sat	-.025	-.014	-.051	-.013	.043	1.000	
Sun	-.025	-.005	-.029	-.019	-.084	-.183	1.000

Figure 3.23. Correlations between air pollution levels, weather factors, and weekends (Rockville - 1973).



	SO_2(1 hr)	SO_2(24 hr)	SI	Av T	Av Wind	Sat	Sun
SO_2(1 hr)	1.000						
SO_2(24 hr)	.872	1.000					
SI	.233	.231	1.000				
Av T	-.272	-.349	.085	1.000			
Av Wind	-.168	-.225	-.233	-.219	1.000		
Sat	.038	.108	-.038	-.016	-.046	1.000	
Sun	-.009	-.001	-.042	-.007	-.014	-.183	1.000

Figure 3.24. Correlations between air pollution levels, weather factors, and weekends (Rockville - 1974).

Figure 3.24 presents the 1974 correlations for Rockville. The results were quite similar to those reported above for 1973. A notable exception was the correlation between average temperature and soiling during 1974 which was quite small and positive.

Silver Spring

A complete set of air pollution measures were available for Silver Spring. Figure 3.25 presents the correlations for 1973. As expected, oxidant levels and average daily temperature exhibited a relatively large positive correlation. No other oxidant correlation was of particular interest. In the second column relating to non-methane hydrocarbons, we note that all pollutants (which does not include oxidants) exhibited positive correlations with non-methane hydrocarbon levels. The largest was the soiling index (.518) followed by the correlation with carbon monoxide (.433). All air pollutants (other than photochemical oxidants) also exhibited positive correlations with nitrogen dioxide, nitric oxide, and carbon monoxide. For nitrogen dioxide the largest was with the soiling index (.456) followed by the correlation with carbon monoxide (.447). For nitric oxide the correlations with carbon monoxide and soiling index were relatively large (.552 and .415, respectively). For carbon monoxide, the correlation with soiling was also large (.649). With regard to the sulfur dioxide measures and the soiling index, one again notes relatively large positive correlations between the sulfur dioxide measures and soiling and negative correlations with average wind speed.

The 1974 Silver Spring correlations are presented in Figure 3.26. The only noteworthy correlation in the first column pertaining to photochemical oxidants is between oxidant levels and average daily temperature (.589). Again, carbon monoxide and soiling had the largest positive correlations with non-methane hydrocarbons (.451 and .274, respectively); their relative magnitudes were reversed. All air pollutants (other than photochemical oxidants) again exhibited positive correlations with nitrogen dioxide; the largest with another air pollutant was with nitric oxide (.428). The correlations with nitric oxide and the remaining air pollutants (column four) were generally smaller. With regard to carbon monoxide (column five) we again note that the largest correlation was with the soiling index (.487). In addition, the sulfur dioxide measures were again positively related to the soiling index and negatively related to average daily temperature and average daily wind speed. Finally, the soiling index again displayed a negative association with average wind speed.

Suitland

The last set of correlation matrices that will be discussed involve data monitored in Suitland, Maryland. Figure 3.27 presents the correlations for the 1973 data. As has been the general case, the oxidant levels were most correlated with average temperature (.697). All of the remaining

	Ox	NM H	NO_2	NO	CO	SO_2 (1 hr)	SO_2 (24 hr)	SI	Av T	Av Wind	Sat	Sun
Ox	1.000											
NM H	-.158	1.000										
NO_2	.074	.271	1.000									
NO	.169	.270	.382	1.000								
CO	.054	.433	.447	.552	1.000							
SO_2(1 hr)	.175	.361	.241	.169	.369	1.000						
SO_2(24 hr)	-.279	.281	.138	.137	.258	.827	1.000					
SI	-.183	.518	.456	.415	.649	.403	.353	1.000				
Av T	.455	.004	.404	.091	.151	-.275	-.439	.030	1.000			
Av Wind	.034	-.308	-.487	-.408	-.427	-.226	-.173	-.437	-.274	1.000		
Sat	-.019	-.111	-.068	-.081	-.140	-.021	-.035	-.146	-.013	.043	1.000	
Sun	-.009	-.119	-.089	-.092	-.160	-.007	-.039	-.275	-.019	-.084	-.183	1.000

Figure 3.25. Correlations between air pollution levels, weather factors, and weekends (Silver Spring - 1973).

	Ox	NM H	NO_2	NO	CO	SO_2 (1 hr)	SO_2 (24 hr)	SI	Av T	Av Wind	Sat	Sun
Ox	1.000											
NM H	-.068	1.000										
NO_2	.195	.199	1.000									
NO	-.073	.099	.428	1.000								
CO	-.105	.431	.282	.236	1.000							
SO_2(1 hr)	-.064	.120	.114	.034	.321	1.000						
SO_2(24 hr)	-.038	.019	.138	.104	.038	.743	1.000					
SI	-.249	.274	.231	.231	.487	.467	.408	1.000				
Av T	.589	-.062	.438	.016	-.147	-.353	-.267	-.138	1.000			
Av Wind	-.128	-.216	-.428	-.207	-.387	-.322	-.337	-.344	-.219	1.000		
Sat	-.003	-.043	-.089	-.155	-.101	-.105	-.066	-.166	-.016	-.046	1.000	
Sun	.038	-.182	-.128	-.126	-.048	-.007	.030	-.166	-.007	-.014	-.133	1.000

Figure 3.26. Correlations between air pollution levels, weather factors, and weekends (Silver Spring - 1974).

	Ox	Nm H	NO_2	NO	CO	SO_2 (1 hr)	SO_2 (24 hr)	SI	Av T	Av Wind	Sat	Sun
Ox	1.000											
Nm H	-.117	1.000										
NO_2	-.202	.272	1.000									
NO	-.207	.428	.446	1.000								
CO	-.115	.362	.297	.628	1.000							
SO_2(1 hr)	-.079	.297	.296	.492	.428	1.000						
SO_2(24 hr)	-.299	.252	.277	.438	.516	.583	1.000					
SI	.009	.223	.267	.369	.326	.322	.298	1.000				
Av T	.697	-.067	-.262	-.176	-.105	-.133	-.373	-.023	1.000			
Av Wind	-.164	-.207	-.210	-.326	-.177	-.181	-.099	-.260	-.274	1.000		
Sat	.032	-.103	-.008	-.121	-.062	.026	.269	-.138	-.013	.043	1.000	
Sun	-.037	-.060	-.226	-.077	-.114	-.131	-.126	-.021	-.019	-.084	-.183	1.000

Figure 3.27. Correlations between air pollution levels, weather factors, and weekends (Suitland - 1973).

	Ox	Nm H	NO_2	NO	CO	SO_2 (1 hr)	SO_2 (24 hr)	SI	Av T	Av Wind	Sat	Sun
Ox	1.000											
Nm H	.163	1.000										
NO_2	.128	.153	1.000									
NO	.146	.039	.429	1.000								
CO	-.048	.406	.043	.053	1.000							
SO_2(1 hr)	.021	.071	.121	.304	.103	1.000						
SO_2(24 hr)	.003	-.020	.166	.330	.024	.652	1.000					
SI	-.160	.187	.078	.035	.281	.076	.168	1.000				
Av T	.625	.134	.183	.125	-.209	-.073	.066	-.335	1.000			
Av Wind	-.167	-.277	-.294	-.169	-.203	-.103	-.042	-.190	-.219	1.000		
Sat	-.047	-.082	-.031	-.039	-.069	-.075	-.059	-.079	-.016	-.046	1.000	
Sun	.048	-.184	-.115	-.164	-.079	-.077	-.034	-.027	-.007	-.014	-.183	1.000

Figure 3.28. Correlations between air pollution levels, weather factors, and weekends (Suitland - 1974).

air pollutants exhibited positive correlations with each other. The largest positive correlation with non-methane hydrocarbons was with nitric oxide (.456) followed by the correlation with carbon monoxide (.362). With regard to nitrogen dioxide, the largest correlation was with nitric oxide (.448). For nitric oxide, the largest correlation was with carbon monoxide (.628). For carbon monoxide, the largest of the remaining correlations was with the twenty-four-average sulfur dioxide reading (.516). Further, the sulfur dioxide measures were again positively related to the soiling index and negatively related to both average daily temperature and average daily wind speed. Soiling was again negatively related to average daily wind speed.

Figure 3.28 presents the 1974 correlation matrix for Suitland. Again, the relatively large positive correlation between photochemical oxidants and average daily temperature dominates the first column. For non-methane hydrocarbons, the only correlation of interest was with carbon monoxide (.406). For nitrogen dioxide, the only correlation of interest was with nitric oxide (.429). Looking at the fourth column pertaining to nitric oxide, we note that all correlations with the remaining air pollutants were positive; the largest being the associations with the two sulfur dioxide measures. For carbon monoxide, the remaining correlations (column five) were relatively small; the largest was with the soiling index (.281). The remaining sulfur dioxide and soiling index correlations were also generally small (except between the two sulfur dioxide measures). The signs of the correlations again indicate positive associations between sulfur dioxide and soiling. Finally, we note that both sulfur dioxide measures and the soiling index were negatively related to average daily wind speed, although the magnitudes were relatively small.

SUMMARY

This chapter has examined the relationships between recorded levels of a specific air pollutant across monitoring stations in metropolitan Washington, D.C., as well as the associations between monitored levels of different air pollutants at a given station. In addition, the relationships between air pollution levels, weather factors, and the occurrence of weekends was investigated. Here, we present some general observations.

Although the national primary and secondary ambient air quality standards for the air pollutants we examined were occasionally exceeded by daily levels of these pollutants at individual monitoring stations, the average readings (on an annual basis) of the air pollutants were generally below the standards.18/ Furthermore, the standard deviations of the individual air pollution series indicated that there was widespread variation in the monitored levels over time.

18/ The major exception was non-methane hydrocarbons which exhibited annual averages in excess of the primary and secondary standard of 0.24 ppm (see Tables 3.3 and 3.4).

The degree of correlation across monitoring stations of a given air pollutant depended on which air pollutant was under consideration. For example, photochemical oxidant levels across stations were more highly correlated than levels of any of the remaining air pollutants examined. Monitored levels of non-methane hydrocarbons, nitrogen dioxide, and nitric oxide exhibited relatively low correlations across stations. Correlations of carbon monoxide levels monitored at different stations exhibited relatively close associations. This was of some interest since readings of carbon monoxide tend to be highly dependent on the specific location of the monitor. The two measures of sulfur dioxide levels also tended to rise and fall together throughout the metropolitan area. Finally, it was noted that the limited data available pertaining to soiling indicated that levels of this air pollutant also exhibited consistent patterns at different monitoring stations.

For many of the air pollutants there was evidence that associated specific monitoring locations with high or low readings. For example, relative to the other stations, low levels of oxidants were monitored at Silver Spring during both 1973 and 1974. With regard to non-methane hydrocarbons, the monitoring stations did not exhibit a consistent pattern. For nitrogen dioxide, average readings monitored at Bethesda tended to be low relative to other stations, while average readings monitored at Silver Spring tended to be high. (Maximum values during both 1973 and 1974 were reported at Suitland.) At the same time, relative to other stations, Suitland reported low average readings of nitric oxide, while Silver Spring reported high average readings. (Bethesda reported the maximum readings of nitric oxide.) At the same time, relative to other stations, Bethesda recorded low carbon monoxide levels; whereas, Gaithersburg recorded high levels. This was somewhat surprising since Gaithersburg is an outlying suburb of metropolitan Washington and one would not expect as dense a concentration of mobile-source emitters.19/ For both measures of sulfur dioxide, relative to other stations, low readings were recorded in Suitland and high readings were monitored at stations in the District of Columbia. Finally, for soiling the lowest readings were recorded at the Rockville monitoring station and the highest readings were monitored in Silver Spring.20/

In looking at the levels of different air pollutants monitored at a given station, some consistent patterns were seen. For example, readings of photochemical oxidants were negatively correlated with readings of the remaining air pollutants, although the magnitudes of the correlations were usually small. At the same time, most of the other air pollutants exhibited positive correlations with each other. (The magnitudes of these relationships exhibited more variation.)

19/ There is, of course, the possibility that the relatively high levels of carbon monoxide monitored in Gaithersburg were an artifact of the specific placement of the monitoring equipment.

20/ We are unaware of point-source emitters in the areas that would give rise to this distribution of air pollution concentrations.

At those stations monitoring both non-methane hydrocarbons and carbon monoxide, a close positive association was often observed. This might be expected since in the Washington Metropolitan Area levels of both of these air pollutants are primarily attributed to mobile-source emissions. A consistent association was also seen between levels of carbon monoxide and the soiling index at stations monitoring both of these air pollution measures.21/ The other noticeably consistent relationships between air pollutants involved both measures of sulfur dioxide and the soiling index. As suggested above, this may have been due to the fact that these air pollutants are generally attributed to stationary sources; hence, on days when such emitters represent important pollution sources, both types of air pollutants may be involved.

In examining the relationships between the monitored levels of the various air pollutants and the two weather variables, average daily temperature and average daily wind speed, several consistent associations were also observed. The most apparent of these was the positive relationships between photochemical oxidant levels and average daily temperature; the magnitude of the correlations was usually in excess of .5. This association, of course, is not surprising since the formation of oxidants depends on a photochemical process. However, it does suggest the difficulties involved in disentangling the independent effects on health status of temperatures and oxidant levels.22/

With regard to average daily wind speed, it was noted that this variable was usually related negatively to monitored levels of the air pollutants examined. This result was also anticipated since wind presumably disperses concentrations of air pollutants that build up in the atmosphere. The negative relationship was most apparent with respect to the soiling index variable. Since the index is a measure of particulate matter, this may have indicated that the particles were being dissipated by the wind.

Finally, with regard to the effects of weekends we noted that although Saturdays and Sundays were generally negatively associated with monitored air pollution levels, the magnitudes of these associations were relatively small. A number of explanations for this can be given. First, in those cases where mobile-sources are thought to be the important pollution emitters, weekend traffic may compensate for commuting traffic during the week. Alternatively, there may be other sources of the observed air pollution levels (both on weekdays and weekends). A third possibility is that the air pollutants may be sufficiently persistent (perhaps because of meteorological factors) that a distinct weekend effect does not take place.23/

21/ We suggested the possibility that significant particulate emissions from automobiles could have led to this association, but we had no way of confirming this.

22/ This problem is made even more formidable since high humidity is also a characteristic of days having high temperatures.

23/ Since our primary concern is with the health effects of air pollution, we did not examine more elaborate lag effects involving only air pollution levels, weather factors, and the occurrence of weekends.

Thus, it would seem that the air pollution profile in the Washington Metropolitan Area (as represented by the District of Columbia and Maryland data) exhibits some degree of uniformity. The implication of this observation is that using only a few air pollution monitoring stations may not seriously bias the measurement of the out-of-doors exposure of the "average" Washingtonian. This conclusion seems especially true with regard to photochemical oxidants, the air pollutant of major interest.24/

24/ This conclusion should not be overinterpreted in light of the fact that air pollution data from northern Virginia were unavailable for analysis.

SECTION IV

EMPIRICAL RESULTS

INTRODUCTION

In our earlier study we found multiple regression to be a useful technique in analyzing the effects of environmental factors on clinic utilization. Given the findings of that study, we began our empirical analyses of the enlarged data base by selecting the general specification used in the earlier work. Specifically, we began by fitting regressions of the following form to the clinic utilization, weather, and expanded air pollution data:

$$UDV_t = \alpha + \beta_1 AP_t + \beta_2 \text{ Av } T_t + \beta_3 \text{ Av Wind}_t + \beta_4 \text{ Sat} + \beta_5 \text{ Sun} + \epsilon$$

where UDV_t represents the number of unscheduled department visits on day t, AP_t represents the air pollution reading on day t, Av T_t is the average temperature for day t, Av Wind_t is the average wind speed for that day, Sat and Sun are weekend dummy variables, ϵ is an error term, and α and βs represent coefficients to be estimated.

In the following tables we present the results of analyzing the above specification. Since interest was focused primarily on the possible health effects of air pollution levels and since the previous study indicated that the weather variables were relatively unimportant in explaining unscheduled department visits, the tables report only the statistics pertaining to the relevant air pollution variable.1/ Specifically, the tables present the estimated regression coefficient, its corresponding t-statistic, and the estimated elasticity about the mean.2/ We discuss the results by specific air pollutant.

PHOTOCHEMICAL OXIDANTS

Table 4.1 presents the estimated effects of photochemical oxidants on unscheduled department utilization, controlling for average daily temperature, average daily wind speed, and weekends. Each column of numbers corresponds to the estimated air pollution effects on unscheduled visitation to a particular department.3/ For example, the first column

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1/ The minimums, means, maximums, and standard deviations of the meteorological variables were presented in Table 3.17. These statistics for the department utilization data are presented in Appendix B.

2/ The elasticity is equal to $10 \times \beta_1 (\overline{AP}/\overline{UDV})$, where β_1 is the estimated coefficient and $\overline{AP}$ and $\overline{UDV}$ are the means of the air pollution and visitation variables, respectively. Its value corresponds to the estimated percentage change in unscheduled visits associated with a 10 percent change in the relevant air pollution level.

3/ Regressions were not run for the 1973 urgent visit clinic data because of a schedule change that occurred during the year.

TABLE 4.1. ESTIMATED EFFECTS OF PHOTOCHEMICAL OXIDANTS ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
D.C. CAMP	-12.317[a]	8.873	13.867	60.424	-22.764	108.631	138.840
	(-1.00)[b]	(0.48)	(1.73)	(4.54)	(-0.83)	(1.87)	(1.34)
	-0.45[c]	0.43	1.11	4.26	-0.31	0.94	0.36
D.C. CP		-28.270		-7.432		-15.353	153.070
		(-1.82)		(-0.61)		(-0.34)	(1.80)
		-1.58		-0.57		-0.15	0.45
Bethesda	-9.613	-19.655	18.385	26.381	-32.393	43.234	111.980
	(-0.93)	(-0.94)	(2.84)	(1.32)	(-1.47)	(0.66)	(0.88)
	-0.40	-1.14	1.54	2.22	-0.46	0.57	0.36
Gaithersburg	2.951	-39.324	2.249	-32.811	-22.981	43.811	44.583
	(0.17)	(-1.52)	(0.20)	(-1.99)	(-0.87)	(0.52)	(0.31)
	0.09	-1.94	0.16	-2.88	-0.27	0.37	0.11
Silver Spring	-12.763	-17.755	19.454	28.865	15.206	-26.682	115.590
	(-0.95)	(-0.77)	(2.29)	(1.46)	(0.53)	(-0.40)	(0.91)
	-0.32	-0.68	1.04	1.65	0.14	-0.23	0.26
Suitland	-5.969	-20.846	9.347	25.501	-50.963	-0.977	85.587
	(-0.47)	(-1.18)	(1.13)	(1.52)	(-1.94)	(-0.02)	(0.86)
	-0.20	-1.46	0.67	2.51	-0.63	-0.02	0.34

[a] The regression coefficient.

[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.

[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; and UVC, urgent visit clinic.

represents the estimated oxidant effects on unscheduled visits to the internal medicine department (UIM). Each row of numbers corresponds to the estimated effects across departments of oxidant levels monitored at a given station. For example, the first row is derived from an analysis of oxidant readings monitored at the District of Columbia CAMP station (D.C. CAMP).4/

Since we are primarily concerned with consistent estimated air pollution effects on unscheduled department utilization, we will discuss the results by specific departments. That is, we will generally refer to the findings column by column. In doing so, we will be looking initially at two types of criteria. The first are positive regression coefficients (see footnote a, Table 4.1) representing positive associations between oxidant levels and unscheduled department utilization. The second are statistically significant t-statistics (see footnote b, Table 4.1) indicating that the estimated coefficients are statistically different from zero. If these two criteria are generally satisfied for a given department in a given year, we will proceed to evaluate the estimated elasticities (see footnote c, Table 4.1). That is, we will examine the magnitudes of the estimated associations.

Looking at the first two columns pertaining to the 1973 and 1974 unscheduled utilization of the internal medicine department, one notes only one statistically significant regression coefficient;5/ and it was negative. Thus, there was no evidence of a positive and significant relationship between monitored levels of photochemical oxidants and unscheduled visitation to the internal medicine department.

For the column pertaining to the 1973 data from the ophthalmology department, one notes that all the regression coefficients were positive and that three of the five were statistically significant. The estimated elasticities corresponding to the statistically significant coefficients ranged from 1.04 (Silver Spring) to 1.54 (Bethesda) indicating that 10 percent decreases in the means of the air pollution variables were associated with between 1.04 and 1.54 percent decreases in the number of unscheduled visits to the ophthalmology department.6/ The data pertaining to 1974 unscheduled visits to the ophthalmology department were less consistent.7/ Only one coefficient (D.C. CAMP) was positive and statistically significant, three were positive and approached statistical significance,8/ one was negative

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4/ The District of Columbia Cleveland Park monitoring station (D.C. CP) did not provide sufficient 1973 photochemical oxidant data to permit analysis.

5/ In the context of this analysis, a factor or variable was considered "statistically significant" if its regression coefficient was significantly different from zero at (at least) the 10 percent level. That is, we had at least 90 percent confidence in the individual statements regarding the association.

6/ We note that the highest annual mean photochemical oxidant level occurred for the readings from Bethesda during 1973 (see Table 3.1).

7/ Note that the annual mean levels of photochemical oxidants during 1974 were generally lower than those for 1973 (see Tables 3.1 and 3.2).

8/ When we use the term "approached statistical significance" we are making a judgment that the estimated t-statistic would have called for rejection of the null hypothesis of no association (that is, a coefficient equal to zero) at a lower level of significance.

and insignificant, and one was negative and significant. Given these mixed findings, we are not emphasizing the estimated elasticities from the 1974 data.

Turning to the 1973 data pertaining to the unscheduled utilization of the pediatric department, we found no evidence of a positive and significant association between unscheduled visits and oxidant levels. Further, the results of analyzing 1974 data revealed only one positive and significant regression coefficient (D.C. CAMP). The remaining coefficients had mixed signs and none was statistically significant.

The 1974 data relating to the urgent visit clinic displayed positive associations between clinic visits and oxidant levels monitored at each station, although only one regression coefficient (D.C. CP) was statistically significant. Given the consistently positive associations, we think it worth noting that the elasticity corresponding to the statistically significant coefficient indicated that a 10 percent decrease in the mean of the air pollution variable was associated with a 0.45 percent decrease in the number of urgent clinic visits.

Taken together, the results for 1973 and 1974 relating photochemical oxidant pollution monitored at various stations in the District of Columbia and Maryland to unscheduled department utilization, generally support the findings of the earlier study. The positive association we found to be most consistent and statistically significant was between oxidant levels and unscheduled visits to the ophthalmology department during 1973. The 1974 utilization data from the ophthalmology department displayed less consistent results. The results pertaining to both the internal medicine and pediatric departments did not evidence significant associations between unscheduled visits and oxidant levels, although only one was statistically significant.

NON-METHANE HYDROCARBONS

The results of substituting readings on non-methane hydrocarbons for photochemical oxidants in the specification reported above are reported in Table 4.2. As can be seen from the first column pertaining to 1973 unscheduled utilization of the internal medicine department, only one regression coefficient (Bethesda) approached statistical significance. In addition, the 1974 replication resulted in all negative coefficients, one of which was statistically significant. Thus, there was no consistent evidence of a positive association between levels of non-methane hydrocarbons and unscheduled internal medicine visits.

Similar results were found for unscheduled visits to the ophthalmology department. The only statistically significant regression coefficient (Bethesda) occurred in the analysis of the 1973 data and it was negative.

For the pediatric department, again there was an isolated significant coefficient (Suitland) in the analysis of the 1973 data; it was positive. However, neither the 1974 replication nor results based on the 1973 air

TABLE 4.2. ESTIMATED EFFECTS OF NON-METHANE HYDROCARBONS ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
D.C. CAMP	0.181[a]		-0.021		0.826		
	(0.27)[b]		(-0.05)		(0.59)		
	0.09[c]		-0.02		0.13		
Bethesda	1.598	-0.102	-1.317	-0.904	-0.168	-2.856	-17.260
	(1.62)	(-0.08)	(-2.21)	(-0.76)	(-0.08)	(-0.70)	(-2.19)
	0.32	-0.03	-0.57	-0.49	-0.01	-0.22	-0.34
Silver Spring	-0.161	-0.030	-0.861	-0.523	0.330	3.181	8.149
	(-0.22)	(-0.03)	(-0.19)	(-0.51)	(0.22)	(0.92)	(1.25)
	-0.03	-0.01	-0.45	-0.35	0.03	0.31	0.21
Suitland	0.409	-2.865	0.162	0.999	2.398	1.317	3.448
	(0.78)	(-1.83)	(0.43)	(0.68)	(2.03)	(0.27)	(0.36)
	0.10	-1.07	0.08	0.55	0.21	0.11	0.07

[a] The regression coefficient.
[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.
[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

pollution data from other monitoring stations supported evidence of a positive association between unscheduled pediatric visits and levels of non-methane hydrocarbons in the Washington Metropolitan Area.

The last column, pertaining to the urgent visit clinic, also did not display consistent evidence of an association. The only statistically significant regression coefficient (Bethesda) was negative.

Thus, as was the case in our earlier study, we did not uncover any consistently significant positive relationships between unscheduled utilization in any department and non-methane hydrocarbon levels.9/ It should be noted that this is despite the fact that readings of non-methane hydrocarbon levels in the Washington Metropolitan Area were frequently in excess of the national primary and secondary standard of 0.24 ppm (see Tables 3.3 and 3.4).

NITROGEN DIOXIDE

Table 4.3 shows the results of substituting nitrogen dioxide levels as the relevant air pollution measure in the same specification. Again, the data pertaining to the internal medicine department did not manifest any positive and significant associations between unscheduled visits and monitored levels of the air pollutant.

The column relating to 1973 unscheduled ophthalmologic visits displayed two statistically significant regressions coefficients; both were negative. It is interesting to note, however, that the 1974 ophthalmologic data displayed all positive and significant regression coefficients. Nevertheless, upon reviewing the statistics pertaining to the 1973 and 1974 nitrogen dioxide readings (Tables 3.5 and 3.6), we failed to find any explanation for this disparity. That is, the monitored nitrogen dioxide levels had similar characteristics in both years. At the same time, the correlations between readings from different stations were generally small, especially for the 1974 data (see Figures 3.6 and 3.7). Thus, we have no basis on which to conclude that the 1974 associations were anything more than artifacts of the particular sample being analyzed.

The data pertaining to the unscheduled pediatric visits during 1973 and 1974 also failed to reveal positive and consistent associations with monitored levels of nitrogen dioxide. The one statistically significant air pollution coefficient (Suitland) was negative.

Finally, one notes that all three air pollution coefficients resulting from the analysis of the 1974 urgent visit clinic data were statistically insignificant; none of the associations was of interest.

9/ The fact that the air pollution coefficients had many mixed signs is not surprising given the relatively low correlations between readings across stations (see Figures 3.4 and 3.5).

TABLE 4.3. ESTIMATED EFFECTS OF NITROGEN DIOXIDE ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
D.C. CAMP	-17.414[a]		3.275		-38.977		
	(-0.78)[b]		(0.23)		(-0.80)		
	-0.60[c]		0.24		-0.49		
Bethesda	-29.802	23.856	-18.397	42.551	16.339	74.188	-23.842
	(-1.84)	(1.03)	(-1.78)	(1.94)	(0.46)	(1.02)	(-0.17)
	-0.89	1.00	-1.23	2.58	0.18	0.68	-0.05
Silver Spring	-14.166	12.565	-16.429	38.128	-42.745	73.791	-9.182
	(-1.04)	(0.65)	(-1.92)	(2.45)	(-1.46)	(1.40)	(-0.09)
	-0.53	0.95	-1.35	3.79	-0.59	1.13	-0.04
Suitland	5.748	-21.331	-6.687	18.903	-18.896	-65.507	-76.109
	(0.39)	(-1.39)	(-0.63)	(1.65)	(-0.54)	(-1.76)	(-0.89)
	0.21	-1.32	-0.52	1.75	-0.25	-0.90	-0.25

[a] The regression coefficient.

[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.

[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

Again, this analysis generally supports the findings of our earlier research. That is, we did not find evidence of consistently significant positive associations between unscheduled utilization in any department and the levels of nitrogen dioxide monitored in the Washington Metropolitan Area.10/

NITRIC OXIDE

The results of substituting nitric oxide readings into the same specification are presented in Table 4.4. The two columns pertaining to the internal medicine department data indicated no positive and statistically significant associations between unscheduled visits and nitric oxide levels. On the contrary, the coefficients that were statistically significant were negative. We have no explanation for this.

Turning to the ophthalmology columns, we note that the Bethesda readings displayed positive and significant associations with unscheduled visits in both years. At the same time, the only other statistically significant coefficient (Silver Spring) evidenced a negative relationship in 1973. 11/ These mixed results do not permit one to draw confident conclusions on the estimated associations.

The analysis relating to unscheduled pediatric visits also showed mixed results. Only one air pollution coefficient (Suitland) was statistically significant; it was positive. However, neither the 1974 replication nor the results based on other 1973 pollution data supported the notion of a consistent and significant positive association between unscheduled utilization of the pediatric department and nitric oxide levels.

All of the nitric oxide coefficients in the analysis of the urgent visit clinic were negative. One, Silver Spring, was statistically significant. Thus, there was no evidence that increased nitric oxide levels were associated with increased urgent clinic visits.

Since nitric oxide data were not monitored in the District of Columbia, our earlier analysis did not examine the relationship between this pollutant and unscheduled department utilization. As we noted earlier (see Section III, footnote 5), interest in this pollutant stems primarily from its importance in the formation of photochemical oxidants. The pollutant itself is thought to be relatively harmless. Thus, our findings are not surprising.

10/Unlike the case with non-methane hydrocarbons, readings were generally at or below the national primary and secondary standard of 0.05 ppm (see Tables 3.5 and 3.6).

11/It is interesting to note that while Silver Spring had the highest annual mean levels of nitric oxide, Bethesda had the highest maximum readings (see Tables 3.7 and 3.8). Furthermore, the correlations between station readings were generally low (see Figures 3.8 and 3.9).

TABLE 4.4. ESTIMATED EFFECTS OF NITRIC OXIDE ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
Bethesda	-2.887[a]	-17.529	0.966	18.980	-1.653	-21.623	-29.136
	(-3.61)[b]	(-3.18)	(1.89)	(3.55)	(-0.96)	(-1.19)	(-0.83)
	-0.49[c]	-1.30	0.34	2.10	-0.10	-0.36	(-0.12)
Silver Spring	1.205	2.988	-2.558	2.175	4.592	6.213	-77.029
	(0.72)	(0.60)	(-2.43)	(0.47)	(1.27)	(0.41)	(-2.68)
	0.23	0.59	-0.10	0.60	0.32	0.26	-0.83
Suitland	5.395	-16.564	-1.931	6.878	21.342	-32.894	-39.825
	(1.57)	(-2.29)	(-0.78)	(1.05)	(2.68)	(-1.57)	(-0.89)
	0.44	-1.34	-0.33	0.88	0.61	-0.64	-0.18

[a] The regression coefficient.

[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.

[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

CARBON MONOXIDE

Table 4.5 displays the estimated effects of carbon monoxide on unscheduled department utilization. One notes in the first column, pertaining to the internal medicine department, that the three statistically significant coefficients were positive indicating that unscheduled internal medicine visits were correlated with increased levels of carbon monoxide monitored at these stations. However, we hesitate to place too much emphasis on these results, since in the 1974 replication, two of the three regression coefficients were negative and statistically significant.

A similar situation is presented by the data representing unscheduled ophthalmology visits. Because of unavailable data, no 1974 replication was possible for the one positive and significant relationship evidenced by the 1973 coefficient (D.C. CAMP). At the same time, the positive and significant coefficients (Silver Spring and Suitland) seen in the 1974 data had corresponding 1973 coefficients that were insignificant and in one case negative. Again, this lack of consistency means we do not have confidence that a "true" association between carbon monoxide levels and unscheduled utilization was present.

For the 1973 pediatric data, all carbon monoxide coefficients were positive and two were statistically significant. However, the 1974 replication evidenced no statistically significant coefficients.

The urgent visit clinic data also evidenced only positive associations with carbon monoxide levels. In this case one was statistically significant.

Thus, for a single year at a time some consistency was displayed between monitored carbon monoxide levels across stations and unscheduled utilization of a given department. However, in each of those cases, the replications for the adjoining year failed to reveal similar associations. Furthermore, upon examining the statistics pertaining to the carbon monoxide readings for the two years (Tables 3.9 and 3.10), one cannot detect important differences that would give rise to these mixed findings. Finally, it should be noted that even if one had confidence of an association between carbon monoxide levels and unscheduled department visits, the estimated elasticities suggest that the magnitudes of the associations were relatively small. Similar conclusions were drawn in the earlier study.

SULFUR DIOXIDE

Table 4.6 presents the estimated effects of sulfur dioxide levels (as measured by the maximum one-hour average) on unscheduled department utilization. Table 4.7 (discussed below) presents similar results based on sulfur dioxide levels (as measured by the 24-hour average).

Although there were two positive and statistically significant air pollution coefficients (D.C. HOSP and Rockville) in the first column pertaining to the 1973 unscheduled internal medicine visits, there was also a negative and significant coefficient (Bethesda). In addition, the only statistically significant air pollution coefficient (D.C. CAMP)

TABLE 4.5. ESTIMATED EFFECTS OF CARBON MONOXIDE ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
D.C. CAMP	-0.077[a]		0.119		0.137		
	(-1.15)[b]		(2.82)		(0.96)		
	-0.41[c]		1.36		0.26		
D.C. HOSP	0.102	-0.065	-0.037	0.000	0.306	-0.025	0.364
	(1.50)	(-0.70)	(-0.83)	(0.01)	(1.97)	(-0.09)	(0.07)
	0.53	-0.56	-0.42	0.00	0.58	-0.03	0.17
Bethesda	0.202	-0.319	-0.131	0.166	0.385	-0.661	0.075
	(1.76)	(-2.00)	(-1.80)	(1.39)	(1.58)	(-1.58)	(0.09)
	0.42	-1.21	-0.57	0.86	0.28	-0.50	0.02
Gaithersburg	0.103	0.047	0.021	0.072	0.445	0.316	0.329
	(1.82)	(0.70)	(0.58)	(1.30)	(3.78)	(1.40)	(0.84)
	0.64	0.46	0.28	1.05	1.00	0.57	0.18
Silver Spring	-0.004	-0.212	-0.089	0.219	0.118	-0.043	0.484
	(-0.05)	(-1.45)	(-1.46)	(1.86)	(0.58)	(-0.11)	(0.62)
	-0.02	-1.46	-0.75	2.00	0.17	-0.05	0.17
Suitland	0.433	-0.282	0.023	0.346	0.135	0.499	1.634
	(3.64)	(-1.78)	(0.28)	(2.73)	(0.52)	(1.17)	(1.91)
	0.97	-1.30	0.10	0.14	0.11	0.46	0.40

[a] The regression coefficient.

[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.

[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three number is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

TABLE 4.6. ESTIMATED EFFECTS OF SULFUR DIOXIDE (MAXIMUM ONE-HOUR AVERAGE) ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
D.C. ACS	7.593[a] (0.72)[b] 0.35[c]		10.680 (1.65) 1.05		23.058 (1.07) 0.38		
D.C. CAMP		-29.222 (-2.17) -1.32		1.511 (0.14) 0.10		-54.658 (-1.25) -0.46	-19.604 (-0.27) -0.05
D.C. HOSP	19.502 (1.78) 0.62		0.781 (0.12) 0.05		18.986 (0.81) 0.22		
Bethesda	-25.978 (-2.34) -0.47	18.132 (0.66) 0.48	-7.212 (-1.04) -0.28	-25.145 (-1.03) -0.85	-1.129 (-0.49) -0.01	-164.640 (-2.14) -0.89	160.840 (1.00) 0.21
Rockville	43.674 (2.54) 0.90	-8.528 (-0.65) -0.36	19.066 (1.75) 0.82	1.808 (0.16) 0.12	54.748 (1.48) 0.40	95.357 (2.16) 0.72	125.040 (1.70) 0.29
Silver Spring	-7.956 (-0.39) -0.11	5.275 (0.15) 0.13	-5.156 (-0.40) -0.15	-17.056 (-0.57) -0.53	27.914 (0.64) 0.14	28.776 (0.29) 0.14	200.480 (1.01) 0.25
Suitland	29.354 (1.05) 0.27	39.003 (1.14) 0.68	21.905 (1.17) 0.40	0.000 (0.00) 0.00	-68.386 (-1.14) -0.23	-119.180 (-1.29) -0.42	-71.170 (-0.38) -0.06

[a] The regression coefficient.

[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.

[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

TABLE 4.7. ESTIMATED EFFECTS OF SULFUR DIOXIDE (TWENTY-FOUR HOUR AVERAGE) ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
D.C. ACS	5.531[a] (0.30)[b] 0.15[c]		9.714 (0.87) 0.57		15.860 (0.42) 0.16		
D.C. CAMP		-75.184 (-2.52) -1.59		4.351 (0.19) 0.14		-99.235 (-1.03) -0.39	-181.83 (-1.11) -0.21
D.C. HOSP	40.164 (1.61) 0.64	23.266 (0.49) 0.40	-3.984 (-0.26) -0.13	26.706 (0.76) 0.66	40.248 (0.76) 0.23	71.873 (0.49) 0.22	-78.974 (-0.30) -0.08
Bethesda	-90.289 (-2.47) -0.51	233.510 (2.90) 1.93	-17.273 (-0.75) -0.21	-135.440 (-1.87) -1.44	-50.038 (-0.65) -0.10	-529.830 (-2.31) -0.90	-24.504 (-0.05) -0.01
Rockville	65.812 (2.36) 0.67	-1.608 (-0.06) -0.03	25.195 (1.43) 0.54	-0.626 (-0.03) -0.02	42.958 (0.72) 0.16	240.300 (2.47) 0.84	433.510 (2.69) 0.46
Silver Spring	17.136 (0.33) 0.09	205.964 (2.57) 1.94	-44.965 (-1.36) -0.50	-50.727 (-0.73) -0.59	58.910 (0.53) 0.11	309.51 (1.32) 0.57	601.250 (1.30) 0.28
Suitland	203.150 (2.01) 0.44	283.961 (3.03) 1.32	122.050 (1.78) 0.52	-33.184 (-0.45) -0.21	462.913 (2.12) 0.36	-15.176 (-0.06) -0.01	18.395 (0.04) 0.01

[a] The regression coefficient.

[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.

[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

explaining 1974 unscheduled internal medicine visits was negative. Hence, we found no consistent evidence that increased sulfur dioxide levels (as measured by the maximum one-hour average) were associated with increased visits to the internal medicine department.

For the ophthalmology department, the 1973 data again evidenced two positive and significant air pollution coefficients (D.C. ACS and Rockville), however, there were no statistically significant pollution coefficients in the 1974 replications. Furthermore, upon reexamining the statistics pertaining to the air pollution readings (Tables 3.11 and 3.13), we failed to discover any important differences in monitored levels for the two years.12/ Hence, we concluded that the 1973 results were not indicative of a "true" relationship between sulfur dioxide levels and ophthalmologic problems.

No air pollution coefficient was statistically significant in the analysis of 1973 unscheduled pediatric visits. For the 1974 data, one pollution coefficient (Rockville) was positive and significant, while another (Bethesda) was negative and significant. Thus, unscheduled pediatric visits did not display a consistent association with monitored sulfur dioxide levels.

With regard to the urgent visit clinic, only one air pollution coefficient (Rockville) was statistically significant; it was positive. This could not be taken as strong evidence of an important association between sulfur dioxide readings and urgent clinic visits.

These results were consistent with those found in our earlier study. Although isolated positive associations between sulfur dioxide levels and unscheduled department utilization were noted at that time, they were never confirmed by the results of replications.

The results of substituting 24-hour averages of sulfur dioxide levels for maximum one-hour averages in the analysis of unscheduled department utilization are shown in Table 4.7. As can be seen in the first column, two air pollution coefficients (Rockville and Suitland) were positive and approached statistical significance. However, the Bethesda coefficient was negative and significant. Furthermore, the 1974 Bethesda coefficient was positive and significant, while neither the 1974 D.C. HOSP nor the 1974 Rockville coefficient was significantly associated with 1974 internal medicine visits.13/ This lack of consistency again deters us from concluding that there was evidence of a "true" positive association.

12/ We do note that the mean value of the maximum one-hour averages of sulfur dioxide readings recording at the D.C. ACS stations during 1973 was substantially higher than that recorded at the other monitoring stations (see Table 3.11).

13/ We note that the District of Columbia stations again recorded relatively higher sulfur dioxide readings than the other monitoring stations and that among the Maryland stations, Rockville recorded the highest readings on average.

Similarly, in looking at the ophthalmology data, we note only one statistically significant coefficient (Suitland) in the 1973 analysis and it was positive, and only one statistically significant coefficient (Bethesda) in the 1974 replication and it was negative. Based on these results, one would not conclude the existence of an important association between opthalmology problems and sulfur dioxide pollution at the levels monitored in the Washington Metropolitan Area.

The analysis of the pediatric department data in conjunction with 24-hour averages of sulfur dioxide levels was analogous to the analyses for the other departments. In the 1973 column one pollution coefficient (Suitland) was statistically significant; it was positive. In the 1974 column the two coefficients (Bethesda and Rockville) that were statistically significant had opposite signs.

Finally, in the last column of the table, only one coefficient (Rockville) was statistically significant in explaining urgent clinic visits. It was positive. However, the coefficients for the other monitoring stations did not consistently support this positive association.

In reviewing Tables 3.12 and 3.14 we failed to uncover characteristics of the monitored sulfur dioxide readings that would give rise to these mixed results. In fact, the monitoring station having the most number of positive and significant coefficients (Suitland) in explaining unscheduled department utilization actually recorded the lowest levels of sulfur dioxide concentrations.

These results are similar to those presented in the earlier study. That is, the original findings were also inconclusive with regard to evidence supporting a positive and consistent association between unscheduled department utilization and sulfur dioxide pollution at levels recorded in the Washington Metropolitan Area.

SOILING INDEX

Table 4.8 presents the results of analyzing levels of the soiling index together with unscheduled department utilization. The two columns pertaining to the analysis of the internal medicine department contain only one statistically significant coefficient (Bethesda in 1973) and the sign of the coefficient suggested a positive association with unscheduled visits. However, neither the 1974 Bethesda coefficient nor the other air pollution coefficients supported this finding.

Turning to the ophthalmology department, we note two positive and significant coefficients (Rockville and Suitland) during 1973 and one negative and significant coefficient (Bethesda). All the 1974 pollution

TABLE 4.8. ESTIMATED EFFECTS OF SOILING INDEX ON UNSCHEDULED DEPARTMENT UTILIZATION

Monitoring Station	UIM		UOPHTH		UPED		UVC
	1973	1974	1973	1974	1973	1974	1974
Bethesda	1.330[a]	-0.890	-0.881	1.117	1.939	-2.146	1.312
	(1.65)[b]	(-1.22)	(-1.73)	(1.87)	(1.12)	(-1.06)	(0.33)
	0.63[c]	-0.72	-0.88	1.25	0.33	-0.36	0.06
Rockville	-1.088	-2.606	1.124	2.248	3.989	20.839	11.976
	(-1.22)	(-1.55)	(2.02)	(2.06)	(2.14)	(3.82)	(1.21)
	-0.37	-1.92	0.80	2.81	0.49	2.17	0.48
Silver Spring	0.266	-0.495	-0.219	0.203	-0.383	3.175	0.376
	(0.58)	(-0.86)	(-0.75)	(0.43)	(-0.39)	(2.02)	(0.12)
	0.24	-0.77	-0.42	0.41	-0.13	0.99	0.03
Suitland	0.717	-0.574	0.918	0.717	-0.045	0.014	0.641
	(1.26)	(-0.94)	(2.50)	(1.45)	(-0.04)	(0.01)	(0.19)
	0.54	-0.56	1.44	0.92	-0.01	0.00	0.03

[a] The regression coefficient.
[b] The t-statistic; a value of 1.65 indicates significance at the 10 percent level, using a two-tailed test.
[c] The elasticity about the mean; values represent the estimated percentage change in unscheduled visits associated with a 10 percent reduction in the relevant air pollution level.

Note: Each set of three numbers is based on a regression that included variables controlling for average daily temperature, average daily wind speed, and weekends (in addition to the air pollution variable).

Abbreviations: UIM, unscheduled internal medicine; UOPHTH, unscheduled ophthalmology; UPED, unscheduled pediatric; UVC, urgent visit clinic.

coefficients were positive; two were statistically significant. These results are suggestive of a possible association between ophthalmology problems and the index of soiling.

Less consistency was seen for the analysis of unscheduled visits to the pediatric department. One 1973 pollution coefficient (Rockville) was statistically significant and it was positive. The two pollution coefficients that were statistically significant in the 1974 replication were also positive. Again, these results may be indicative of an association between soiling and unscheduled pediatric visits.

Finally, the last column pertaining to the urgent visit clinic indicates that none of the air pollution coefficients was statistically significant, although all had positive signs. Since a 1973 analysis was not possible, these results are not sufficient to suggest an important association between levels of soiling and urgent clinic visits.

No data were available in our earlier study for analyzing the effects of soiling index levels on department utilization; hence, no comparison can be made. Based on findings reported above using data from the Maryland monitoring stations, we conclude that possible associations exist between daily soiling index levels and daily unscheduled department utilization. Nevertheless, the evidence is sufficiently weak that we would not emphasize the magnitudes of these estimated associations.

THE EFFECTS OF OTHER METEOROLOGICAL VARIABLES

Thus far we have reported results that were based on a specification containing only two meteorological variables, average daily temperature and average daily wind speed. Here, we investigate the effects of including and substituting additional climatic variables based on measures of relative humidity. Specifically, we reanalyzed models pertaining to photochemical oxidant effects on unscheduled department utilization. We chose to reanalyze this air pollutant because the results above indicated that levels of oxidants were most consistently associated with health effects as measured by unscheduled department utilization. (These reanalyses are not shown.)

First, we added a variable representing the daily average humidity to the basic specification examined above that contained variables representing oxidant levels, average daily temperature, average daily wind speed, and weekends. Then, we substituted a variable representing the maximum daily humidity for the average daily humidity in a similar specification.14/ In each case we were analyzing the data to see first if the previously estimated associations between air pollution levels and unscheduled utilization were stable and second, to determine what, if any, effects humidity levels had on unscheduled utilization. We hypothesized that, other things being equal, those days having higher humidity levels would be characterized by having increased unscheduled department utilization.

14/ The maximum measure was analyzed to see if extreme humidity conditions were more important than average levels. As one would expect, the simple correlation between the two measures of humidity was quite high; it exceeded .85 for the data from each year.

Next, we eliminated the average daily temperature variable and the humidity variables and replaced them with one of the two variables representing the temperature humidity index (THI) discussed in Section III. Again, our primary concern was with the stability of the originally estimated relationships. Secondary interest was on the association between the temperature humidity indices and unscheduled utilization. We hypothesized that, other things being equal, those days having higher values of the temperature humidity indices would be days on which there was increased unscheduled utilization of the departments.

In general, the inclusion and substitution of these climatic variables did not greatly affect the magnitude and significance of the previously estimated coefficient of the photochemical oxidant variable. For those departments where a positive and statistically significant relationship between oxidant levels and unscheduled utilization had been found, this remained the case when the humidity variables were added or the temperature humidity indices were substituted. Similarly, for those departments where no association had been seen, this remained the case. These findings were analogous to those in the earlier study, since we had also found that the estimated associations were sufficiently robust that inclusion or substitution of additional meteorological variables failed to have significant effects.

With regard to the climatic variables themselves, several consistent relationships were observed. As discussed above, the addition of the daily average or daily maximum humidity variable did not appreciably change the magnitude or significance of the coefficient of the oxidant variable. Nevertheless, the coefficients of the humidity variables consistently displayed negative signs and they were often statistically significant. Thus, while controlling for photochemical oxidant levels, temperature, wind, and weekends, there was some indication that days with higher humidity readings were characterized by less unscheduled utilization of the departments. This seems somewhat counter-intuitive and we have no explanation for it.

Turning to the temperature humidity indices, we found slightly different results. Again, we noted above that the substitution of the temperature humidity indices for the separate temperature and humidity variables did not have an important effect on the coefficient of the oxidant variable. In this case, however, the relationship between the temperature humidity indices and unscheduled department utilization was less consistent than that of the humidity variables described above. Specifically, the direction of the association between the THI variables and unscheduled utilization was dependent upon which department was under consideration. In those cases where the coefficient of the index variable was statistically significant, it was usually positive, indicating that higher values of the index were associated with increased unscheduled utilization. This was especially true for visits to both the internal medicine department and urgent visit clinic during 1974. That is, controlling for oxidant levels, wind, and weekends, days associated with higher values of the temperature humidity indices usually experienced

relatively higher unscheduled utilization of these two departments. Since the temperature humidity index was constructed to represent a measure of physical discomfort, these findings were in the expected direction.

SUMMARY

The major portion of this section presented the empirical results of analyzing the air pollution, meteorological, and health data. Regression results were discussed in which these data were analyzed by specific air pollutant. The order of pollutants was: photochemical oxidants, non-methane hydrocarbons, nitrogen dioxide, nitric oxide, carbon monoxide, sulfur dioxide, and soiling index. Following these discussions, the effects of including and substituting additional meteorological variables were discussed.

With respect to the air pollution variable of primary interest, photochemical oxidants, the regression results were generally similar to those of the earlier study. As before, the most consistent, positive and statistically significant association was between oxidant levels and unscheduled visits to the ophthalmology department. This was particularly true for the 1973 data; the 1974 data were less consistent. The magnitude of the association based on the 1973 results indicated that a 10 percent decrease in oxidant levels was related to between a 1.0 and 1.5 percent decrease in unscheduled ophthalmologic visits. In addition, there was a suggestive association between photochemical oxidant levels and 1974 urgent clinic visits; however, both the statistical significance and the magnitude of the association were smaller than the associations pertaining to the ophthalmology department. Furthermore, we did not have 1973 data to test these findings for consistency.

The results for non-methane hydrocarbons and nitrogen dioxide were also similar to the earlier study based on the more limited air pollution data. There was no consistent evidence of a positive and statistically significant association between levels of either of these two air pollutants and unscheduled department utilization.

In our earlier work, no data were available on nitric oxide levels in the Washington Metropolitan Area. When such data were analyzed in this study, there was no evidence of consistent, positive associations between nitric oxide levels and unscheduled department utilization. As noted, this air pollutant is primarily of interest in its role as a precursor to the formation of photochemical oxidants. Since it is thought to be relatively harmless by itself, our findings were not surprising.

With regard to the analysis of carbon monoxide levels, some consistency during single years was displayed between elevated levels of this type of air pollution and unscheduled department utilization. However, in each case, replications based on data from a second year failed to demonstrate similar associations.15/ Furthermore, even in those instances

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15/ Reexamination of the carbon monoxide data for the two years did not provide an explanation for these mixed results.

where consistency for a single year was observed, the magnitudes of the relationships were relatively small.

Two measures of sulfur dioxide were also examined. As before, isolated positive and statistically significant associations between levels of this air pollutant and unscheduled department utilization were noted. However, replications again failed to confirm these relationships. Furthermore, reanalysis of the 1973 and 1974 sulfur dioxide statistics could not explain these disparate findings.

Finally, data were analyzed on readings of a soiling index in conjunction with unscheduled department utilization. These data were unavailable for the earlier research; hence, no comparison could be made. Nevertheless, the results of the analyses were suggestive of possible associations between levels of soiling and unscheduled department utilization. However, the associations were sufficiently weak that we did not emphasize their magnitudes.

The last section of this chapter briefly assessed the basic specification we had used by including and substituting additional weather variables. As in our earlier study, alterations in the specification did not have a great effect on the previously estimated associations. Furthermore, the climatic variables themselves did not seem to be important explanatory variables of department utilization.16/

16/ There was some indication that other things being equal, humidity levels were negatively related to unscheduled utilization and that temperature humidity indices were positively related to unscheduled utilization. While at first these findings may seem inconsistent, at least two factors may explain them: (1) multicollinearity problems due to the high correlation between temperature and humidity, and (2) ceteris paribus, the effects of high temperature dominate the effects of high humidity.

SECTION V

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SECTION V

APPENDICES

APPENDIX A

AIR POLLUTION PROFILE - MARYLAND STATIONS

Air Pollutant	Primary Standard	Secondary Standard	Monitoring Station	Method	Type of Average	Number of Observations	Number of Times Standard Exceeded
Photochemical Oxidants	0.08 ppm[a,b]	0.08 ppm[a,b]	Bethesda Gaithersburg Silver Spring Suitland	Chemiluminescence " " "	max. 1-hr. " " " " " "	346[c] (174)[d] 365 (236) 349 (195) 307 (178)	81[c] (31)[d] 36 (16) 25 (11) 47 (46)
Non-Methane Hydrocarbons	0.24 ppm[a,e]	0.24 ppm[a,e]	Bethesda Silver Spring Suitland	Flame Ionization[f] " "	3-hr. " "	300 (147) 324 (179) 252 (170)	107 (62) 139 (94) 101 (79)
Nitrogen Dioxide	0.05 ppm[g,h]	0.05 ppm[g,h]	Bethesda Silver Spring Suitland	Colorimetric " "	max. 1-hr. " " " "	365 (176) 319 (221) 219 (190)	na
Carbon Monoxide	9 ppm[a,i] 35 ppm[b]	9 ppm[a,i] 35 ppm[b]	Bethesda Gaithersburg Silver Spring Suitland	Non Dispersive Infrared " " "	" " " " " " " "	365 (222) 360 (342) 349 (223) 292 (225)	0 (0) 2 (1) 0 (0) 0 (0)
Sulfur Dioxide	0.14 ppm[a,h] 0.03 ppm[g]	0.50 ppm[a,j] 0.50 ppm[a,j]	Bethesda Silver Spring Suitland Rockville	Pararosanaline " " West-Gaeke Colorimetric	max. 1-hr. & 24-hr. " " " " " "	313 (178) 336 (209) 242 (215) 350 (278)	0 (0) 0 (0) 0 (0) 0 (0)
Soiling Index	k	k	Bethesda Rockville Silver Spring Suitland	Transmittance " " "	max. 1-hr. " " " " " "	347 (206) 337 (118) 352 (225) 314 (231)	na
Nitric Oxide	m	m	Bethesda Silver Spring Suitland	Colorimetric " "	max. 1-hr. " " " "	365 (159) 320 (165) 225 (150)	na

*Monitoring Station Locations

Bethesda - National Institute of Health
Wisconsin Avenue.
Gaithersburg - Environmental Laboratory
600 S. Fredrick Avenue.
Rockville - County Office Building
101 S. Perry Street.
Silver Spring - Argyle Community Building
Okinawa Road.
Suitland - Suitland Federal Center
Suitland Parkway.

a - Not to be exceeded more than once a year.
b - Based on maximum one hour average.
c - Data for 1973.
d - Data for 1974.
e - Based on 3-hour average (6:00 am - 9:00 am).
f - Readings were obtained by measuring separately total hydrocarbons and methane.
g - Annual arithmetic mean.
h - Based on 24-hour averages.
i - Based on 8-hour averages.
j - Based on 3-hour averages.
k - No national ambient standards for soiling index (standards for suspended particulates not applicable).
m - No national ambient standard for nitric oxide.

APPENDIX B

STATISTICS ON DAILY DEPARTMENT UTILIZATION VARIABLES USED IN THE STUDY

	Minimum		Mean		Maximum		Standard deviation	
Department	1973	1974	1973	1974	1973	1974	1973	1974
Internal Medicine	0	0	13	8	34	46	8.5	7.7
Ophthalmology	0	0	6	5	20	37	4.6	6.0
Pediatrics	0	0	36	44	79	151	19.4	29.2
Urgent Visit Clinic	--	2	--	123	--	324	--	44.4